

TOPICS IN WATER USE: NORTHEASTERN MISSOURI



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Introduction

According to the Missouri Water Resources Law (RSMo 640.400), the state water resources plan is to address water needs for the following uses: drinking, agriculture, industry, recreation and environmental protection. Addressing water “needs” requires us to establish why these needs exist in the first place. In some cases, an existing water need is tied to one or more unresolved water problems. For example, communities “need” clean water. To meet this need, communities may have to address problems with water supply infrastructure and source water quality. This report explores current issues facing the water resources of the northeastern Missouri region. It also includes a brief section addressing recent successes that various water-related programs have enjoyed, and how they have affected the water resources of the region.

To ensure equal consideration for all uses, emphasis was initially placed on identifying water use problems in each topical area identified in the Water Resources Law. Recognizing that individual problems are usually associated with more than one topical area, however, references to usage categories have been excluded in this report. This enables us to acknowledge the true complexity of these problems, and helps us remove barriers to water planning rather than create and perpetuate them.

Although considered individually in this report, water use problems are not truly independent of each other. When reading the water use problems identified in northeastern Missouri, it will quickly become apparent that many of them are, in fact, very

closely related. In addition, because of the diverse perspectives the various contributors bring to this effort, what from one standpoint may appear to be a “serious problem” may not seem so from another. For these reasons, the following problems underscore the importance of working cooperatively in addressing the water use problems facing northeastern Missouri.

As water resource professionals, we commonly subdivide the state into physiographic units, such as watersheds or aquifers. While this approach is important for resource-based discussions, it may not sufficiently address water use problems or solutions. In this series of reports, we have chosen to address the subject using the broad geographic similarities of the six field service areas of the department’s Division of Environmental Quality (DEQ) (figure 1). Each of these regions has distinctive physiographic features and socioeconomic characteristics, and therefore were chosen for the ease of referencing water use problems. This approach allows us to recognize Missouri’s diversity, and lends itself well to this phase of the State Water Plan.

The area served by the Division of Environmental Quality’s Northeast Regional Office is the focus of this report. Staff from this office and other state agencies dealing with water resources were the primary sources of input for this effort. This enables us to draw upon the insight and experience of field staff who, by virtue of their work, deal with many water use issues facing northeastern Missouri on a daily basis.

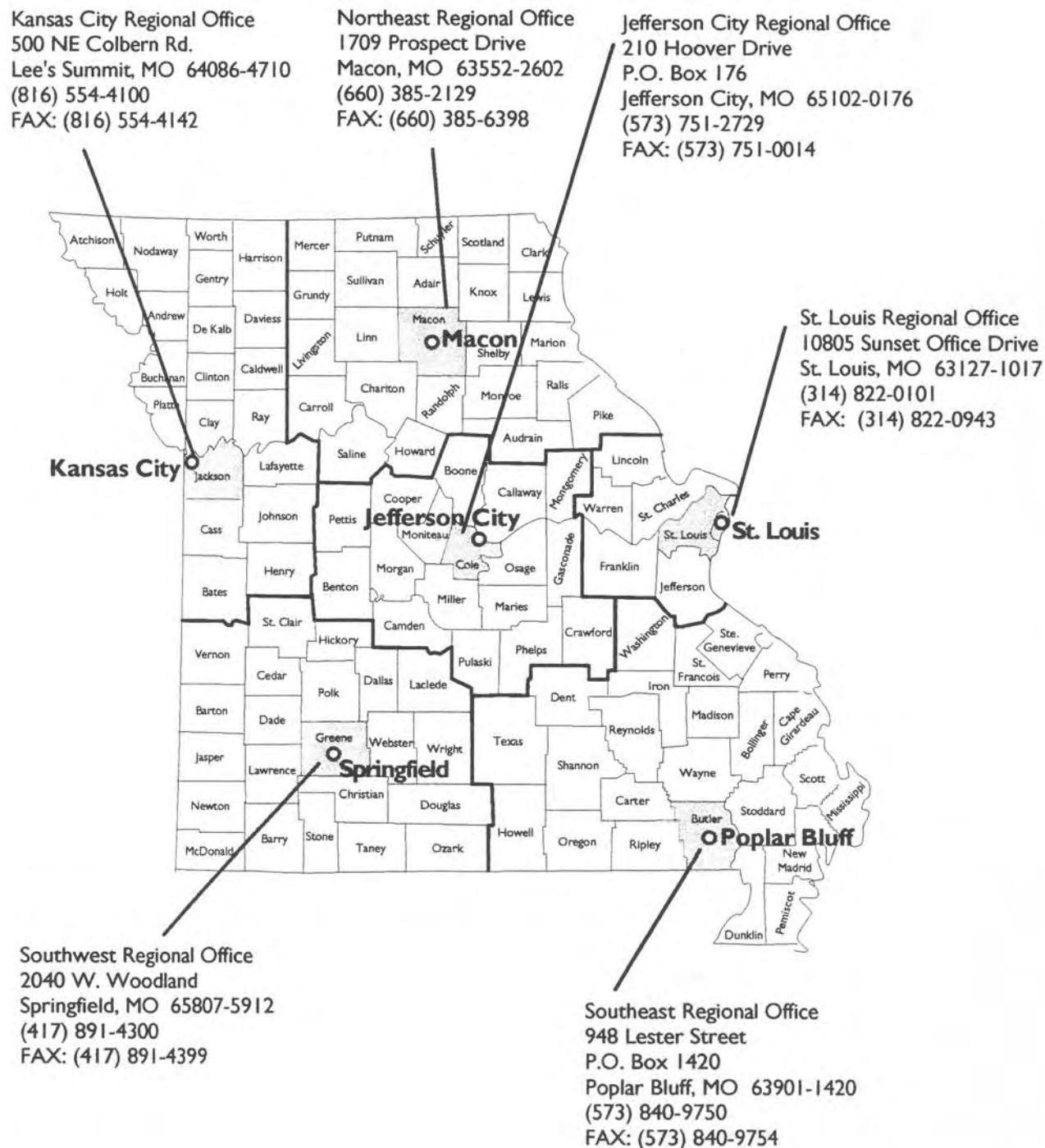


Figure 1. Missouri Department of Natural Resources' Division of Environmental Quality Regional Offices.



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Regional Description

The Missouri Department of Natural Resources Division of Environmental Quality has six regional offices located throughout the state. These offices are designated by the area in which they are located and include the Kansas City, Southwest, Southeast, St. Louis, Jefferson City, and Northeast regional offices. Each office has responsibilities for environmental issues within a particular area, defined on the basis of county boundaries.

Within the jurisdiction of the DEQ Northeast Regional Office are 24 counties in extreme northeastern Missouri. These counties are Mercer, Grundy, Livingston, Carroll, Saline, Howard, Chariton, Linn, Sullivan, Putnam, Schuyler, Adair, Macon, Randolph, Audrain, Monroe, Shelby, Knox, Scotland, Clark, Lewis, Marion, Ralls, and Pike (figure 2). The state of Iowa is the northern boundary and the Des Moines and Mississippi rivers combine to form the eastern boundary of the region. Five of the counties of northeastern Missouri front on the Mississippi River, and four of the counties are located along the Missouri River. These counties have a long history of settlement, and their life-styles are oriented toward the river.

Colleges and Universities

The counties in this region are home to numerous colleges. The list includes Culver-Stockton College at Canton (Lewis County), Hannibal-LaGrange College at Hannibal (Marion County), Missouri Valley College at Marshall (Saline County), Central Methodist College at Fayette (Howard County), Harry S Truman University, previously Northeastern Missouri State University at Kirksville (Adair County), North Central Missouri College at Trenton (Grundy County), Moberly Area Community College at Moberly (Randolph County),

and Missouri Military Academy at Mexico (Audrain County) (figure 3).

Regional Transportation

Motor vehicle transportation in the region is provided by several national highway routes, as well as a number of state highways and local roads (figure 4). The state highway department is presently converting additional sections of several highly traveled roads to divided multilane highways. In addition, several freight railways cross the area (figure 5). Kansas City is a common western destination while Chicago and St. Louis are common eastern destinations. Freight trains run between a number of cities in the region, and railway passenger service is provided by AMTRAK connecting Kansas City and Chicago. Air travel provides another means of transportation, with regional airports located at Mexico, Kirksville and Moberly. Numerous small and private airfields are located throughout the region. Finally, the Mississippi and Missouri rivers provide avenues for commercial navigation and recreational boating. Barge terminals (docks) are located at Miami, Glasgow, Howard County (across from Boonville), Gregory Landing, LaGrange, Hannibal, Louisiana, and Clarksville (figure 5).

Population Characteristics

Hannibal, with 18,004 people, is the largest city in the region. The second largest city in the region is Kirksville, in Adair County (table 1). Total population for the northeastern region, according to the 1990 census, was 294,629 (table 1). This represents an average of 22.1 persons per square mile. Fifty-

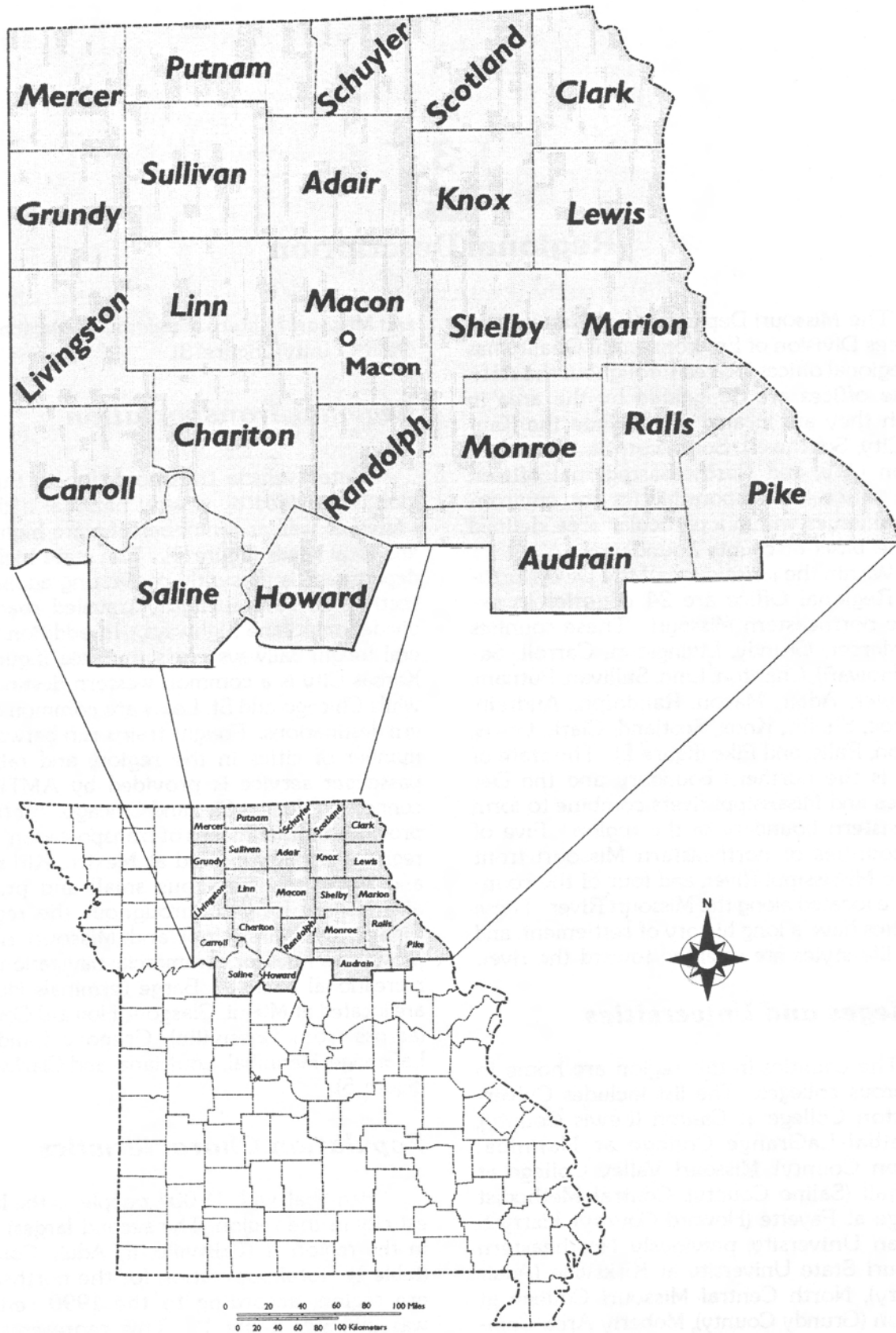


Figure 2. Counties of the Division of Environmental Quality Northeast Missouri Region.



Figure 3. Locations of universities and colleges in northeastern Missouri.

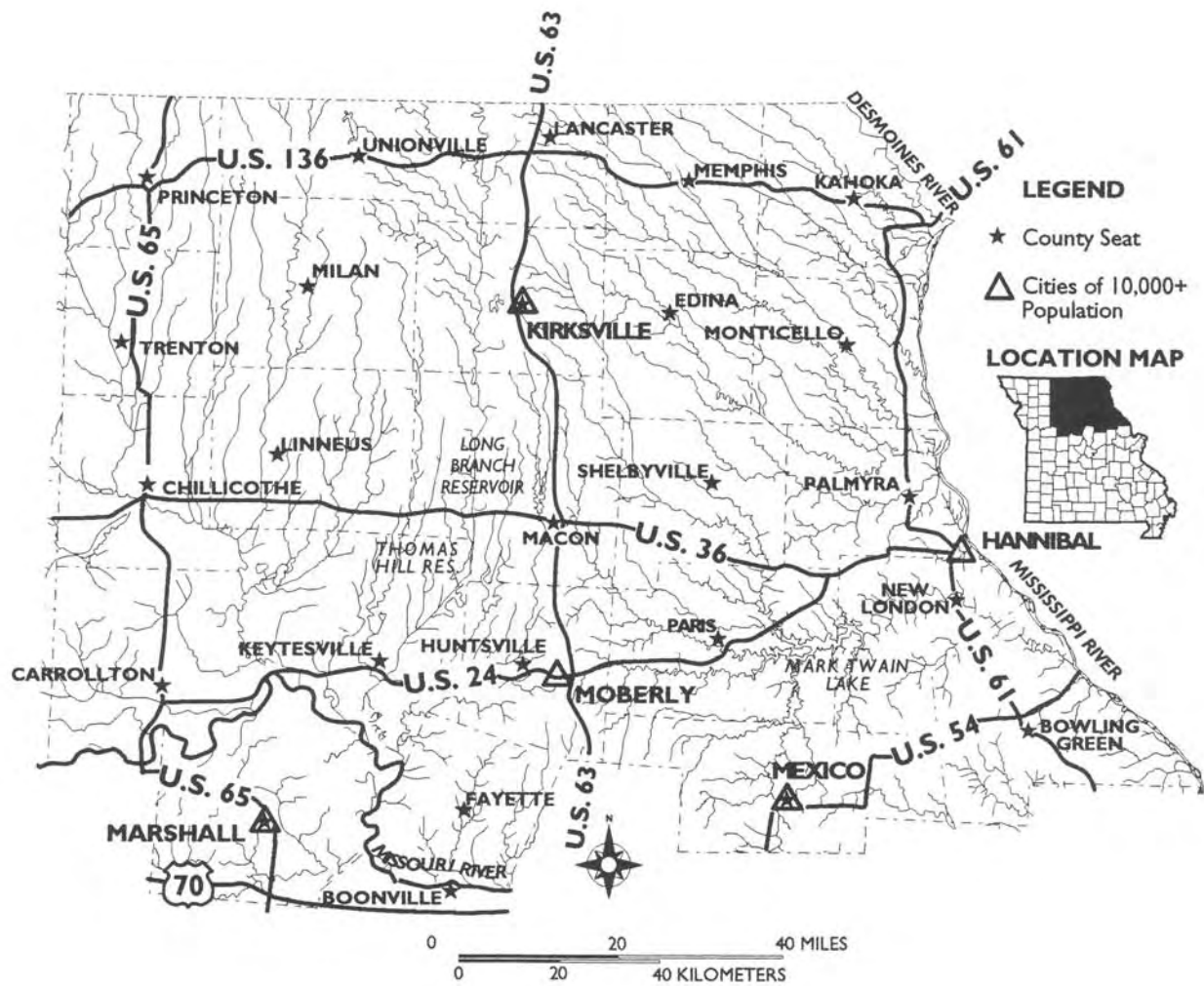


Figure 4. Major roads, cities, streams and reservoirs in northeastern Missouri.

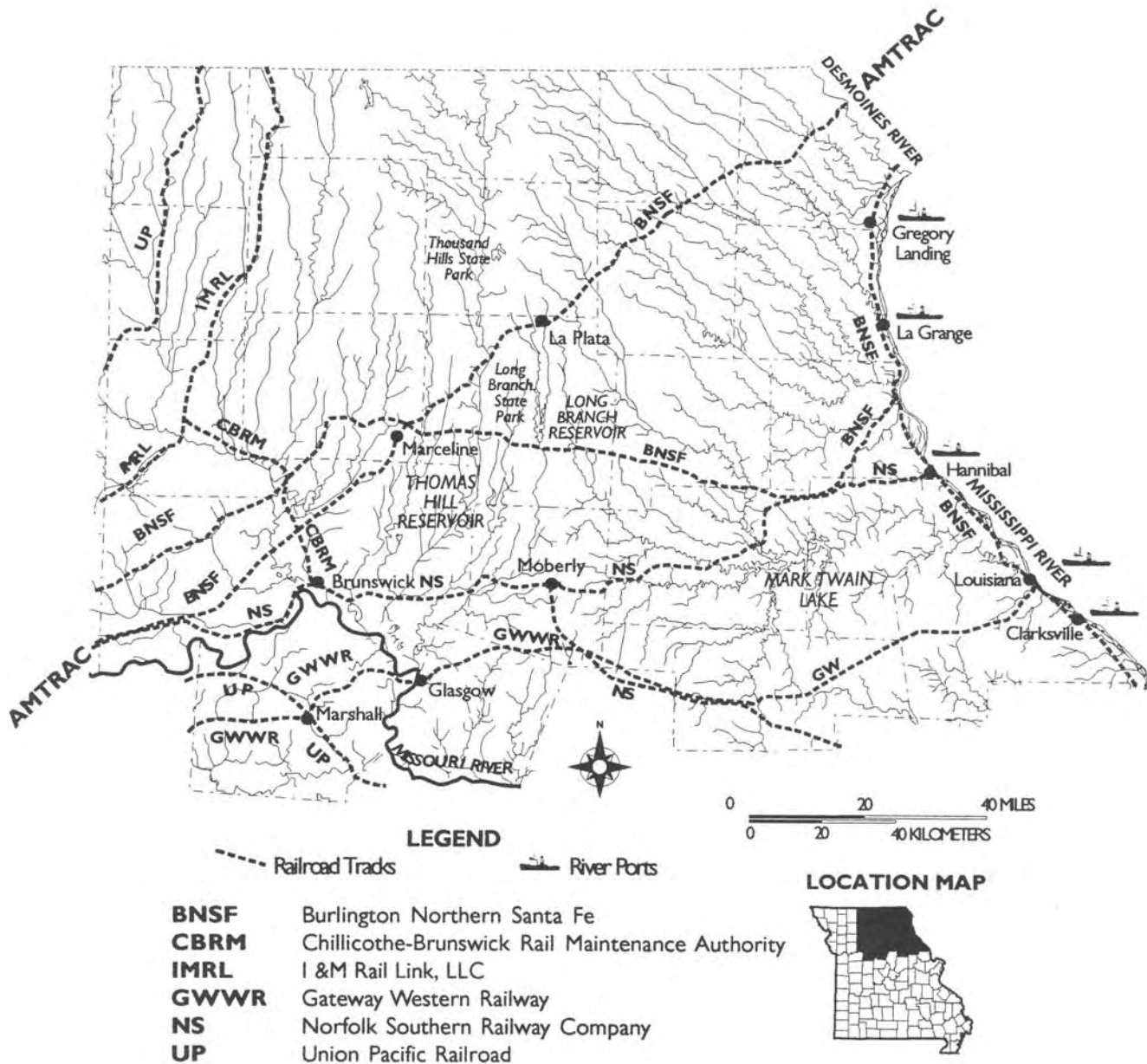


Figure 5. Railroads and barge terminals in northeastern Missouri.

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County name/Population	County seat/Population	Major Town(s)/Population	River Port
Adair - 24,577	Kirksville - 17,152		
Audrain - 23,599	Mexico - 11,290	Vandalia - 2,683	
Carroll - 10,748	Carrollton - 4,406		
Chariton - 9,202	Keytesville - 564	Salisbury - 1,881	Brunswick - 1,074
Clark - 7,547	Kahoka - 2,195	Wayland - 420	Gregory Landing (uninc.)
Grundy - 10,536	Trenton - 6,129		
Howard - 9,631	Fayette - 2,888	New Franklin - 1,107	Glasgow - 1,295
Knox - 4,482	Edina - 1,283		
Lewis - 10,233	Monticello - 106	Canton - 2,623	LaGrange - 1,102
Linn - 13,885	Linneus - 364	Brookfield - 4,888 and Marceline - 2,645	
Livingston - 14,592	Chillicothe - 8,779		
Macon - 15,345	Macon - 5,571	LaPlata - 1,401	
Marion - 27,682	Palmyra - 3,371		Hannibal - 18,004
Mercer - 3,723	Princeton - 1,021		
Monroe - 9,104	Paris - 1,486	Monroe City - 2,701	
Pike - 15,969	Bowling Green - 2,976		Louisiana - 3967 and Clarksville - 480
Putnam - 5,079	Unionville - 1,989		
Ralls - 8,476	New London - 988		
Randolph - 24,370	Huntsville - 1,567	Moberly - 12,839	
Saline - 23,523	Marshall - 12,711	Slater - 2,186	Miami - 142
Schuyler - 4,236	Lancaster - 785		
Scotland - 4,822	Memphis - 2,094		
Shelby - 6,942	Shelbyville - 582	Shelbina - 2,172 and Clarence - 1,026	
Sullivan - 6,326	Milan - 1,767		

Table 1. Population data for northeastern Missouri counties (data source: Missouri. Secretary of State, Official Manual, State of Missouri, 1995-1996).

two and a half percent of the population in the 24-county region was female. Rural residents accounted for 57.4 percent of the total population. By age groups, 28.3 percent of the population was less than 20 years old, 26.9 percent was 20-39, 25.7 percent was 40-64 and, 19.1 percent was 65 or older. The median age was 37.7. The 1990 census identified 131,136 housing units and 114,106 households within the region. (OSED, 1996) (table 2).

Education statistics list 14.5 percent of the region's population aged 25 or older with less than a ninth grade education. 15.6 percent had education beyond the ninth grade but had not graduated from high school, 40.5 percent held high school diplomas, 11.5 percent had received college degrees, and 4.0 percent held graduate degrees. Employment and income data show 17.0 percent of the workforce were managers/professionals, 23.1 percent held technical/sales/administrative positions, 14.3 percent were employed in a service industry, 9.3 percent in farming, forestry and fishing, and 30.1 percent in "other" employment sectors. The unemployment rate for the region was at 6.2 percent. The average annual household income was \$24,381 and the average home value was \$28,583. Approximately 16.8 percent of the region's residents were at or below the poverty level (OSED, 1996) (table 2).

Industry, Commerce and Agriculture

Industry in the northeastern region is varied. Retail trade and service-oriented businesses top the list of industries in all counties, followed by manufacturers, construction companies, transportation and wholesale trade (USDC, 1994). Agricultural and related services are located in a number of counties within the region, including Carroll, Linn, Livingston, Marion, Pike, Saline, and Shelby counties. Two large cement plants are located adjacent to the Mississippi River, one near Hannibal, and the other near Clarksville.

The northeastern region of Missouri can be described as having gently rolling hills and fairly extensive plains that are conducive to production of livestock and agriculture crops. Some loess deposits (windblown silt) along the Missouri and Mississippi rivers have fairly

high natural fertility and are favorable for intensive agriculture. Corn, soybeans, hay, wheat, alfalfa, and sorghum are the primary crops grown in the region. In 1992, half of the 24 counties in the region had higher crop sales than livestock sales (OSED, 1996).

This region is host to northern Missouri's greatest concentrations of hogs and pigs, sheep and lambs, and beef cattle. Hog and pig production in Mercer, Putnam and Sullivan counties accounts for almost a million animals, more than all the other counties in the region combined. Schuyler County boasts the greatest lamb and sheep production of any northern Missouri county. Dairy cattle, though not as prevalent here as in other parts of the state, are nonetheless integral components of this region's livestock. In addition, several counties within the region support high levels of poultry production.

Physical Characteristics

Northeastern Missouri has a humid, continental climate with average annual temperatures from about 52° F to 55° F. Long-term annual precipitation averages from 35 to 38 inches throughout the region (figure 6), with extremes ranging from 20 to 65 inches (Vandike, 1995). Rainfall amounts are generally highest in the spring and lowest in the fall and winter months. Evapotranspiration, the process of precipitation being returned to the air through direct evaporation or by transpiration of plants, consumes from 26 to 30 inches of the annual rainfall. Surface runoff of precipitation averages from seven to nine inches annually in the area.

The northeastern region of Missouri lies in the glaciated plains of the Central Lowlands physiographic province (figure 7). During the last period of glaciation in Missouri, previously eroded Pennsylvanian- and Mississippian-age rocks in northern Missouri were scoured by melting, but still advancing ice sheets. The result is a combination of preglacial and postglacial erosional surfaces.

Glacial till, composed of sand, clay, silt, gravel and boulders, deposited in previous erosional valleys, can be quite thick--up to several hundred feet (Brookshire, 1997). The glacial till is constantly being dissected by runoff and this erosion is gradually destroying the

Population of region	294,589
Population per square mile	22.1
Number of rural residents	169,042
Population younger than 20 years old	83,537 (28.4%)
Population between 20 and 39 years old	79,147 (26.9%)
Population between 40 and 64 years old	75,772 (25.7%)
Population 65 years old or older	56,173 (19.1%)
Median age	37 years, 7 months
Number of households	114,106
Average household income	\$24,381
Number of people below poverty level	49,397
Total persons aged 25+ with less than a 9th grade education	27,953
Total persons aged 25+ with a 9th to 12th grade education	30,023
Total persons aged 25+ with high school diplomas	77,999
Total persons aged 25+ holding undergraduate degrees	22,064
Total persons aged 25+ holding graduate degrees	7,642
Unemployed	8,341 (2.8%)
Population employed in management and professional occupations	22,846 (7.8%)
Population employed in technical, sales or administrative occupations	30,928 (10.5%)
Population employed in service occupations	19,173 (6.5%)
Population employed in farming, forestry or fishing	12,482 (4.2%)
Population employed in other occupations	40,326 (13.7%)
Number of housing units	131,136
Average home value	\$28,583

Table 2. Summarized census data for northeastern Missouri counties (data source: United States Department of Commerce, Bureau of the Census, 1990).

level plains-like topography. The resulting drainage pattern consists of nearly parallel streams trending south or southeasterly (Vandike, 1995).

Beneath the glacial till, sedimentary rocks of Pennsylvanian age, primarily shales and sandstones and Mississippian-aged limestones make up most of the surface geology in northeastern Missouri. However, a northwest-trending band of Ordovician rocks appears at the surface in eastern Ralls and Pike counties (figure 8). The sedimentary rocks also appear in sequence at depth in the subsurface where they lie upon a very thick sequence of carbonate rocks, Ordovician and Cambrian in age that are mostly dolomites. Underlying the carbonate sequence are igneous and metamorphic rocks of Precambrian age forming the basement rock (table 3).

Northeastern Missouri is drained directly or indirectly by the Missouri and Upper Mississippi rivers (figure 9). Within these two watersheds, smaller streams and rivers provide drainage. All or part of the following river basins are located in the northeastern region: Grand, Thompson, Chariton, Little Chariton, Des Moines, Fox, Wyaconda, Fabius, North, Salt, Cuivre, and Blackwater rivers, and Shoal, Medicine, Locust, and Yellow creeks (figure 10).

The flow characteristics of most rivers in this region are similar. Groundwater inflow into streams is generally low, and flow in the streams is very low or nonexistent during times of extended drought¹ conditions. Minimal storage of water in streambanks combined with a lack of sustained streamflow lead watersheds to respond somewhat rapidly to storm events. Flash runoff following heavy rainfall events often causes excessive sediment loading in the area's streams. Pesticides found in runoff

from agricultural fields may have impacts as well. Although it depends on use, overall water quality is generally good. Most of the towns in the Upper Mississippi River basin depend upon surface water for public water supply and either use an intake in a river or draw water from a reservoir (Vandike, 1995). Major lakes in the region are Thomas Hill Reservoir in Randolph County, Long Branch Lake in Macon County, and Mark Twain Lake in Monroe and Ralls counties (figure 4).

Groundwater resources in most of the northeastern region are poor due to inadequate quantity and marginal quality, although shallow domestic wells into the glacial till generally yield enough fair quality water for household use. Water quality differs dramatically across the area and at depth and is dependent upon the geologic characteristics of the bedrock aquifer, such as the composition of glacial material. Generally, the deeper the aquifer is, the more mineralized its water. Sulfate, chloride, sodium, iron, and manganese are all constituents that can have impacts on water quality in the region.

Recreation

The gently rolling hills, plains, and numerous lakes in northeastern Missouri provide a scenic backdrop for seven state parks, eight state historic sites, numerous wildlife refuges and conservation areas (tables 4 and 5). All types of water recreation, including fishing, sailing, swimming, canoeing, water-skiing, and motor boating are readily available within the area. Two commercial caves located near Hannibal in Marion County provide a window to the area's geological characteristics and illustrate some of northeastern Missouri's interesting history.

¹ The Missouri Drought Response Plan defines drought as a water shortfall in some component of the hydrologic cycle. Low soil moisture levels indicate "agricultural" drought conditions, declining surface water and groundwater supplies indicate "hydrological" drought conditions, and a lack of precipitation is indicative of "meteorological" drought.

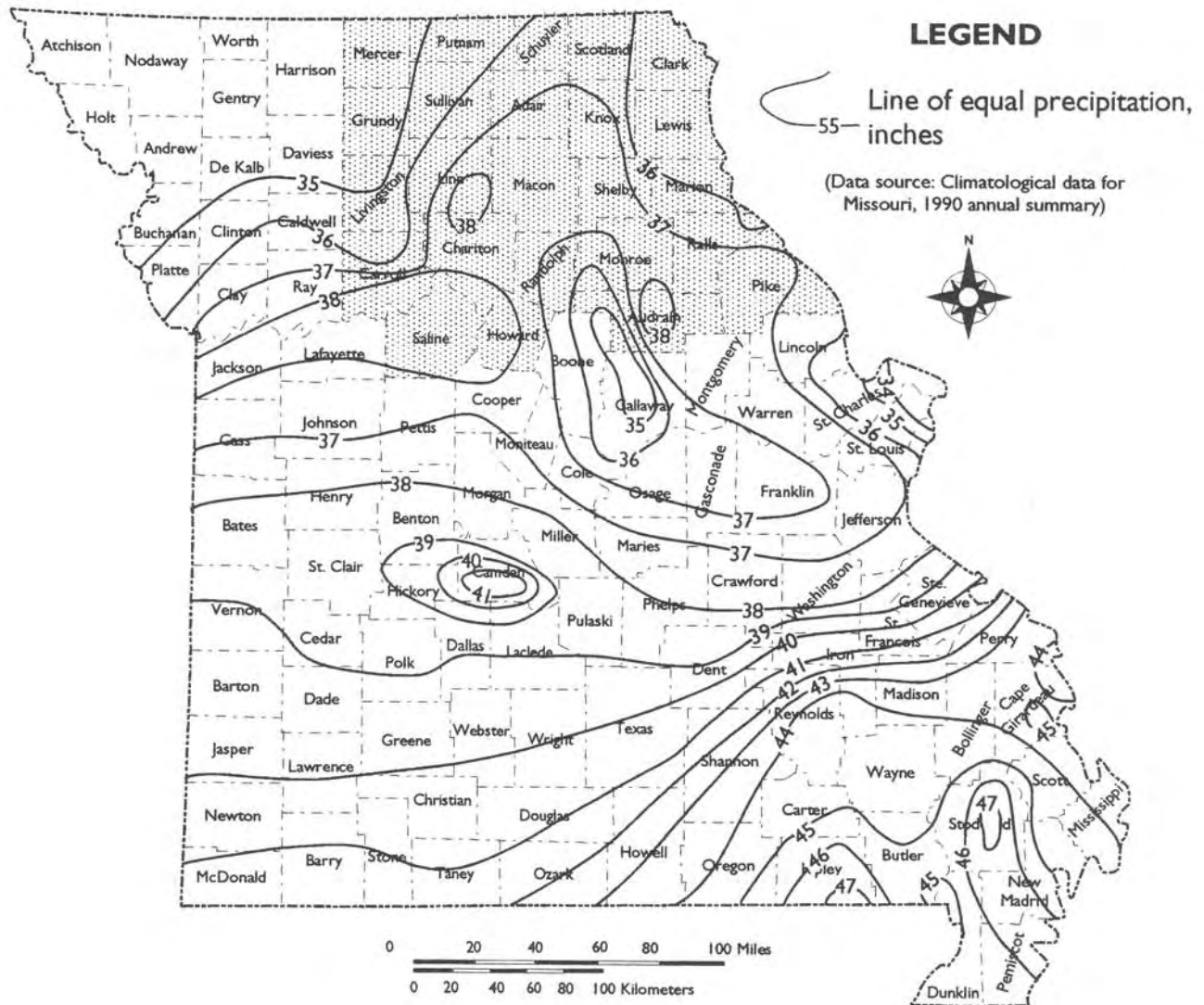


Figure 6. Average annual precipitation for Missouri (Source: Climatological data for Missouri, 1990 annual summary).

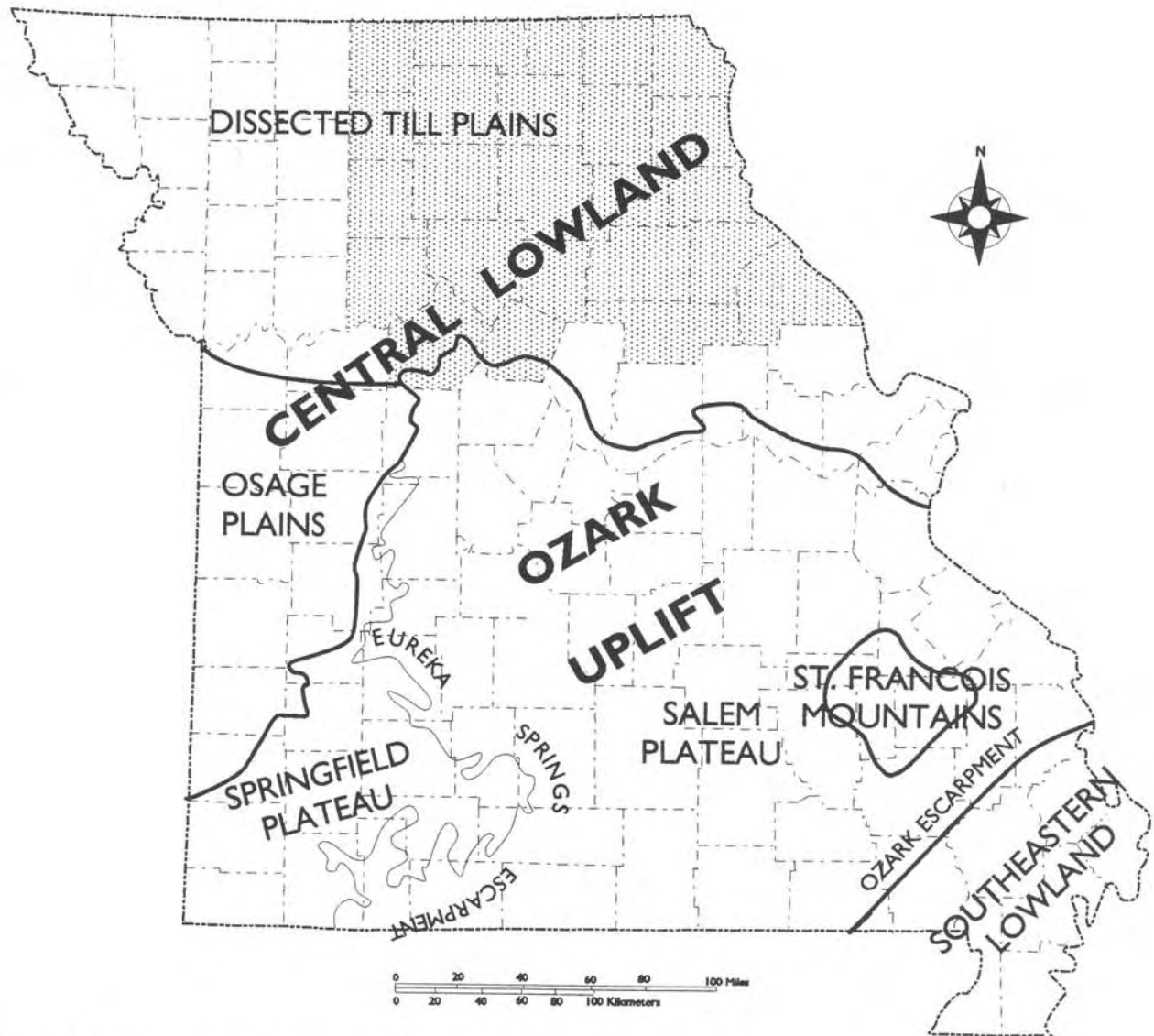


Figure 7. Physiographic regions of Missouri (after Vandike, 1995).

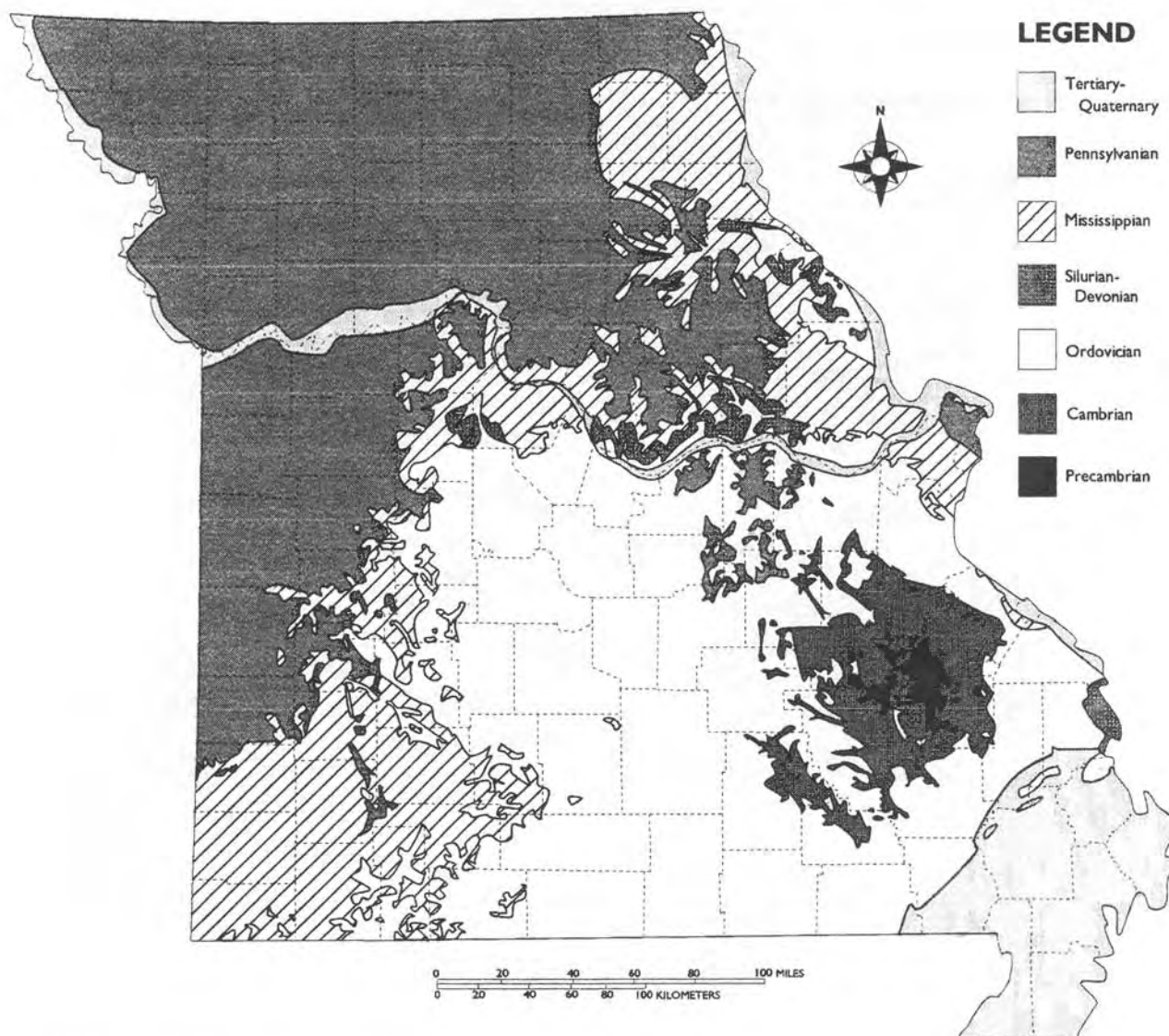


Figure 8. Generalized geologic map of Missouri (after Vandike, 1995).

SYSTEM	SERIES	GROUP	GEOLOGIC UNIT	HYDROGEOLOGIC UNIT
Quaternary	Holocene		Alluvium	Missouri and Mississippi rivers and in Mississippi embayment, 500-2000 gpm. Yields are less along smaller rivers
	Pleistocene		Loess, till, and other drift, sand and gravel	Drift and till typically yield 0-5 gpm. Drift-filled preglacial valleys typically yield 50-500 gpm.
Tertiary	(undifferentiated)			Wilcox Group (Mississippi embayment only), 50-400 gpm.
Cretaceous	(undifferentiated)			McNairy formation (Mississippi embayment only), 200-500 gpm.
Pennsylvanian	(undifferentiated)			Northern and west-central Missouri, 1-20 gpm, regionally forms a confining layer.
Mississippian	Chesterian		(undifferentiated)	
	Meramecian		(undifferentiated)	Springfield Plateau aquifer
	Osagean		Keokuk Limestone Burlington Limestone Grand Falls Formation Reeds Spring Formation Pierson formation	Southwest, central, and eastern Missouri, 5-30 gpm.
	Kinderhookian	Chouteau	Northview Formation Sedalia Formation Compton Formation	Ozark confining unit
			Hannibal Formation	
	Devonian	(undifferentiated)		
	Silurian	(undifferentiated)		
	Cincinnatian		Orchard Creek shale Thebes Sandstone Maquoketa Shale Cape Limestone	
	Champlainian		Kimmswick Formation Decorah Formation Plattin Formation Joachim Dolomite Dutchtown Formation St. Peter Sandstone Everton Formation	Ozark aquifer (upper) Yield is greatest from St. Peter Sandstone Yields of 5 to 50 gpm are possible.
	Canadian		Smithville Formation Powell Dolomite Cotter Dolomite Jefferson City Dolomite Roubidoux Formation Gasconade Dolomite Gunter Sandstone Mbr.	Ozark aquifer (lower) Yields vary greatly with location and well depth. In Salem Plateau, yields are typically 50-500 gpm. In Springfield Plateau and central Missouri, yields are typically 500 to 1200 gpm.
Cambrian	Upper Cambrian		Eminence Dolomite Potosi Dolomite	
		Elvins	Derby-Doerun Dolomite Davis Formation	St. Francois confining unit.
			Bonnetterre Formation Lamotte Sandstone	St. Francois aquifer Yields of 10 to 100 gpm are possible.
Precambrian	(undifferentiated)		Igneous, metasediments, and other metamorphic rock.	Not a significant aquifer

Table 3. Generalized section of Missouri's geologic units (after Vandike, 1995).

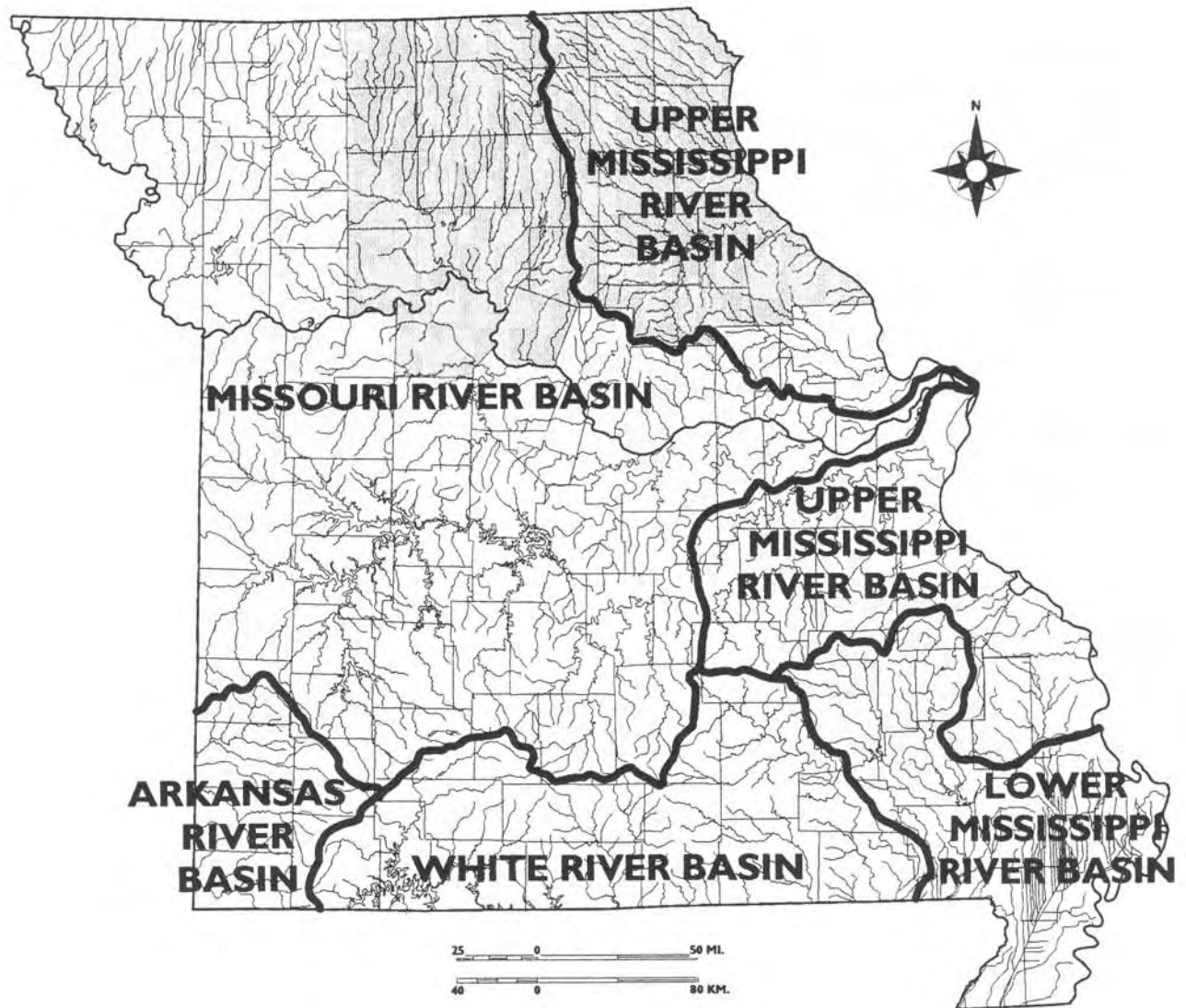


Figure 9. Major drainage basins in Missouri.

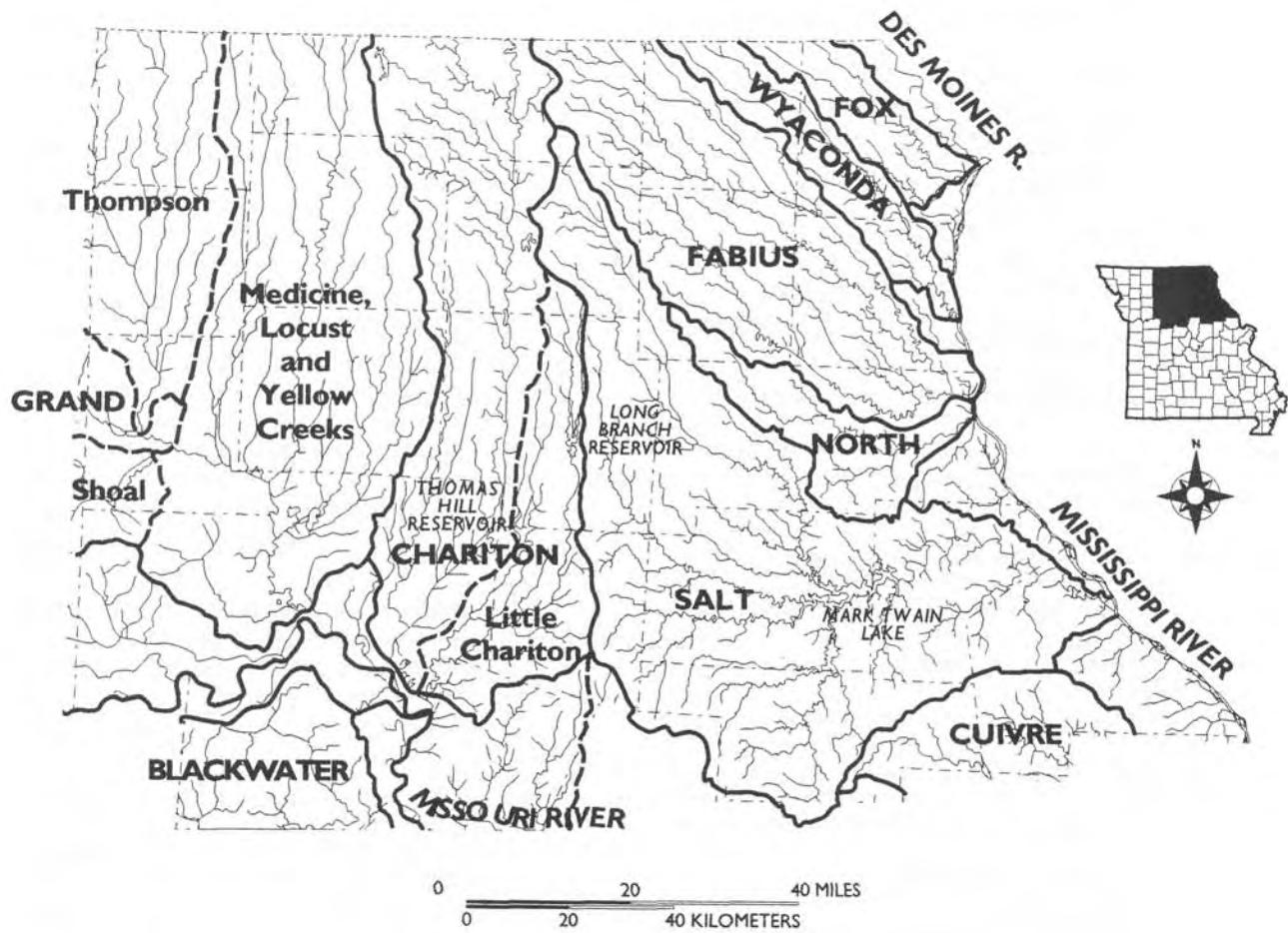


Figure 10. Secondary drainage basins in northeastern Missouri.

WILDLIFE AREA	COUNTY
Big Muddy National Fish and Wildlife Refuge	Saline
Swan Lake National Wildlife Refuge	Chariton
Anderson Conservation Area	Pike - Ralls
Atlanta Conservation Area	Macon
Blind Pony Conservation Area	Saline
Buck Run Conservation Area	Clark
Deer Ridge Conservation Area	Lewis
DuPont Reservation	Pike
Ewing Lake Conservation area	Scotland
Fountain Grove Conservation Area	Linn - Livingston
Grand Pass Conservation Area	Saline
Griffith Memorial Conservation Area	Macon
Heath Memorial Conservation Area	Clark
Henry Sever Conservation Area	Knox
Hungry Mother Conservation Area	Howard
Lake Paho Conservation Area	Mercer
Marshall Junction Conservation Area	Saline
Neeper Wildlife Area	Clark
Northcutt Memorial Conservation Area	Audrain
Pin Oak Conservation Area	Shelby
Ranacker Conservation Area	Pike
Ray Memorial Conservation Area	Marion
Rebel's Cover Conservation Area	Putnam
Redman Wildlife Area	Macon
Renzelman and Schifferdecker Conservation Area	Carroll
Rudolf Bennitt Conservation Area	Randolph - Howard
Ted Shanks Conservation Area	Pike
Thomas Hill Conservation Area	Macon
Willingham Memorial Conservation Area	Monroe

Table 4. State and federal wildlife areas in northeastern Missouri (data source:Missouri Department of Conservation,1996).

FEATURE	NEAREST CITY	COUNTY
Crowder State Park	Trenton	Grundy
Long Branch State Park	Macon	Macon
Mark Twain State Park	Stoutsville	Monroe
Pershing State Park	Laclede	Linn
Thousand Hills State Park	Kirksville	Adair
Van Meter State Park	Miami	Saline
Wakonda State Park	LaGrange	Lewis
Arrow Rock State Historic Site	Arrow Rock	Saline
Battle of Athens State Historic Site	Athens	Clark
Boone's Lick State Historic Site	Boonesboro	Howard
Locust Creek Covered Bridge State Historic Site	Laclede	Linn
Mark Twain Birthplace State Historic Site	Stoutsville	Monroe
Pershing Boyhood Home State Historic Site	Laclede	Linn
Sappington Cemetery State Historic Site	Arrow Rock	Saline
Union Covered Bridge State Historic Site	Paris	Monroe

OTHER HISTORIC SITES

General Omar Bradley Birthplace	Clark	Randolph
Santa Fe Trail Starting Point	Franklin	Howard
Walt Disney Boyhood Home	Marceline	Linn

MAJOR LAKES

Hunnewell Lake	Hunnewell	Shelby
Long Branch Lake	Macon	
Mark Twain Lake	Florida	Marion - Ralls
Lake Paho	Princeton	Mercer
Thomas Hill Reservoir	Thomas Hill	Randolph -Macon
Lake Thunderhead	Unionville	Putnam

Table 5. State parks, major lakes, covered bridges and historic sites (from Missouri Department of Transportation state highway maps and Missouri Department of Natural Resources' Division of State Parks).



Regional Water Use Overview

The following description of water use in northeastern Missouri is included to provide context for the water use problems identified in this report. The categories used below are the same as those used by the United States Geological Survey (USGS) in the National Water-Use Information Program. Most of the water use data provided in this section was collected through this program. Many of the water use problems included in this report address drinking water and agricultural issues, demonstrating the importance of those uses to the region. Domestic and agricultural applications are the predominant water uses of

northeastern Missouri. As shown in figure 11, domestic, irrigation and livestock water use combined account for 78.1 percent of northeastern Missouri's total water use, 43.6 million gallons per day (USGS, 1997 [Online])². Several of the following topics also illustrate the importance of industrial water use to the region. Industrial water use, while not as prevalent as agricultural or domestic water use, is still substantial; 1990 USGS water use data indicates that users consumed nearly 8.5 million gallons of water daily for industrial purposes, 15.2 percent of the region's total water use.

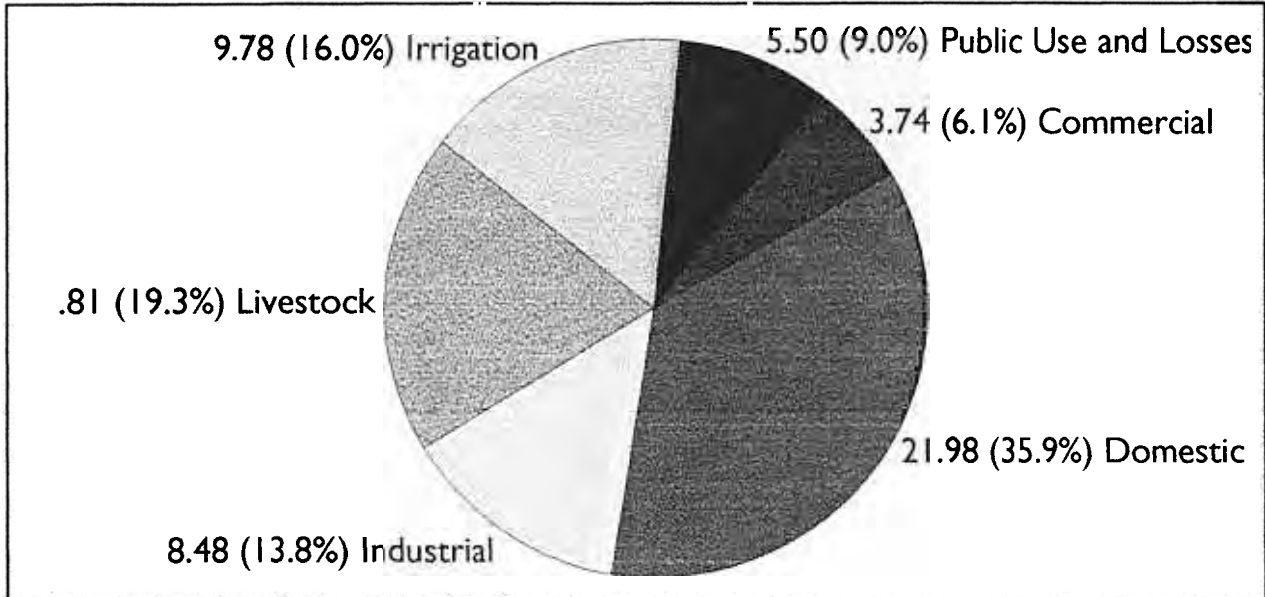


Figure 11. Overall water usage in northeastern Missouri, in million gallons per day (Source: United States Geological Survey, 1990).

² Thermoelectric and hydroelectric power generation are by far the largest categories of water use, but actually consume very little water. To avoid distortion of water usage percentages, it is not shown on Figure 11. Because water is not withdrawn from its source, instream flow usage is also not shown in Figure 11.

Domestic Water Use

Water used for household purposes (such as cooking, washing clothes and bathing) is known as domestic water use. Excluding thermoelectric and hydroelectric power generation, domestic water use is the predominant use of water in northeastern Missouri. The National Water-Use Information Program of the U.S. Geological Survey (USGS) estimated 1990 domestic water use at slightly more than eight billion gallons (USGS, 1990). Estimates of per capita usage were approximately 1,418 gallons per day for self-supplied users and 1,729 gallons daily for those on public water supply³. While most of northeastern Missouri's domestic water requirements are supplied by public water supply systems, many residents of northeastern Missouri use self-supplied water. Approximately 55,190 people in northeastern Missouri relied upon self-supplied water sources in 1990 (USGS, 1997 [Online]). USGS data indicates that 100 percent of self-supplied domestic water withdrawals came from groundwater sources, although it is likely that a small percentage of users actually obtained water from surface water sources⁴.

Industrial and Commercial Water Use

Industrial water use is defined by the USGS as "water used for industrial purposes such as fabrication, processing, washing and cooling, and includes steel, chemical and allied products, paper and allied products, mining, and petroleum refining." Industrial water use in northeastern Missouri is comparatively low. The USGS estimated 1990 industrial water withdrawals to be approximately 8.48 million gallons per day, or 3.1 billion gallons throughout the year. Industrial water users in northeastern Missouri typically rely on self-sup-

plied water rather than public supplies. In 1990, industrial users in northeastern Missouri received only 419 million gallons from public water suppliers, 13.6 percent of their total water use (USGS, 1997 [Online]). Self-supplied withdrawals were taken from both surface and groundwater sources. The USGS water use data indicates that nearly three-quarters of northeastern Missouri's industrial water use occurred in two counties--Marion and Pike. 1990 USGS data shows no industrial water use of any kind in 12 of the northeastern region's 24 counties.

Commercial water use, defined by the USGS as "water for motels, hotels, restaurants, office buildings, other commercial facilities, and institutions," totaled slightly more than 1.36 billion gallons in 1990. Commercial water use in northeastern Missouri is much more dependent upon public water supply deliveries than industrial use, with self-supplied water accounting for 37 percent of the total amount used. Unlike industrial water use, commercial water usage was reported in every county in northeastern Missouri.

Public Water Supply

Although some citizens and businesses in northeastern Missouri use self-supplied water taken from private wells or surface water intakes, the majority receive their water from public water supply sources. Public water supplies are defined by the Department of Natural Resources as systems serving at least 25 persons or 15 service connections. The disposition of water from public supplies (in this case, community systems, such as public water supply districts and municipal water supplies) in northeastern Missouri is indicative of the rural, agricultural lifestyle of the region. USGS data indicates that the percentage of water delivered from public supplies allocated to commercial and "public uses" in

³ Calculated by dividing total withdrawals by total population served, and includes withdrawals for "public use" such as firefighting, street cleaning, and other community needs. Per capita water use calculations, which are based on the sum of personal uses (such as cooking, cleaning and bathing), typically fall between 100 and 200 gallons per day.

⁴ In the 1990 U.S. Census of Population and Housing, approximately 5,000 housing units in northeastern Missouri reported using "some other source" for water, a catchall category which the Census Bureau defines as "water obtained from springs, creeks, rivers, lakes, cisterns, etc."

northeastern Missouri is very similar to that for the state as a whole. Industrial water use, however, accounted for just 4.1 percent of deliveries from public water supplies in northeastern Missouri in 1990, compared to 19.7 percent for the entire state. The percentage of water delivered to domestic users in northeastern Missouri is approximately 67 percent, compared to 51.4 percent for all of Missouri (USGS, 1997 [Online]).

Public water use is defined by the USGS as “water supplied from a public water supply and used for such purposes as firefighting, street washing, and municipal parks and swimming pools.” Public water use also includes transmission losses--water lost from leaking pipes and joints while in transit to domestic, commercial and industrial users. The percentage of public water supply deliveries allocated to public use is very similar to that for the entire state. Public water suppliers in northeastern Missouri distributed 19.7 percent of their deliveries to public uses in 1990, compared to 20.2 percent provided for public use statewide (USGS, 1997 [Online]).

Residential water rates for communities in northeastern Missouri are among the highest in the state, largely because of the limited quantity and marginal quality of groundwater reserves. Because adequate groundwater supplies are scarce, surface water supplies support two-thirds of the population; bedrock aquifers, shallow alluvial wells and several buried channels supply the rest. Northeastern Missouri is extensively served by public water suppliers. Four out of every five citizens of northeastern Missouri receive water from public water supplies. Although a substantial proportion of the population draws upon groundwater reserves, public water supply wells are notably absent in most parts of northeastern Missouri (figure 12). Surface water intakes for public supply, on the other hand, are widely available in this corner of the state (figure 13).

Agricultural Water Use

Farmers in northeastern Missouri use water to irrigate crops and supply livestock. Although irrigation water use far exceeds water use for livestock watering statewide, livestock watering uses slightly more water than irriga-

tion in the northeast (figure 14). Surface water sources account for most of northeastern Missouri's agricultural water use. Approximately 58 percent of irrigation withdrawals in northeastern Missouri come from surface water sources, in sharp contrast to the statewide value of 6 percent. In 1990, two-thirds of the 7.9 billion gallons used for agriculture in northeastern Missouri was taken from the region's lakes and streams (USGS, 1997 [Online]). Since 1990, changes such as the expansion of concentrated animal feeding operations (CAFOs) have further increased the amount of water used in agricultural operations.

Farmers in northeastern Missouri used almost 3.6 billion gallons of water to irrigate their fields in 1990 (USGS, 1997 [Online]). That year, nearly 60 percent of the region's irrigation water use occurred in Audrain County. Audrain County irrigators withdrew slightly more than two billion gallons, a level of use exceeded only in the counties of the Bootheel region. Most of the more productive aquifers of northeastern Missouri are highly saline, making them poor sources of irrigation water. Excessively saline water can damage soil, impairing its productivity over an extended period of time (Hagan, et. al., 1967).

Livestock water use in northeastern Missouri surpassed irrigation withdrawals in 1990, with usage exceeding 4.3 billion gallons of water. Three-fourths of livestock water withdrawals were from surface water sources, a proportion consistent with that of the state as a whole. Unlike irrigation, livestock production is distributed across the region. A wide variety of livestock is raised in northeastern Missouri, each of which must have access to water throughout the year.

Water Use in Power Production

Thermoelectric power generation, the burning of fossil fuels to generate electricity, uses water in several ways. A small amount of high quality water circulates through the boiler to drive the turbines, but the predominant use of water in thermoelectric power generation is to cool the power plant. This allows the high quality water used in the boiler to be recirculated, and also allows electricity to be generated more efficiently (DuCharme and Miller, 1996).

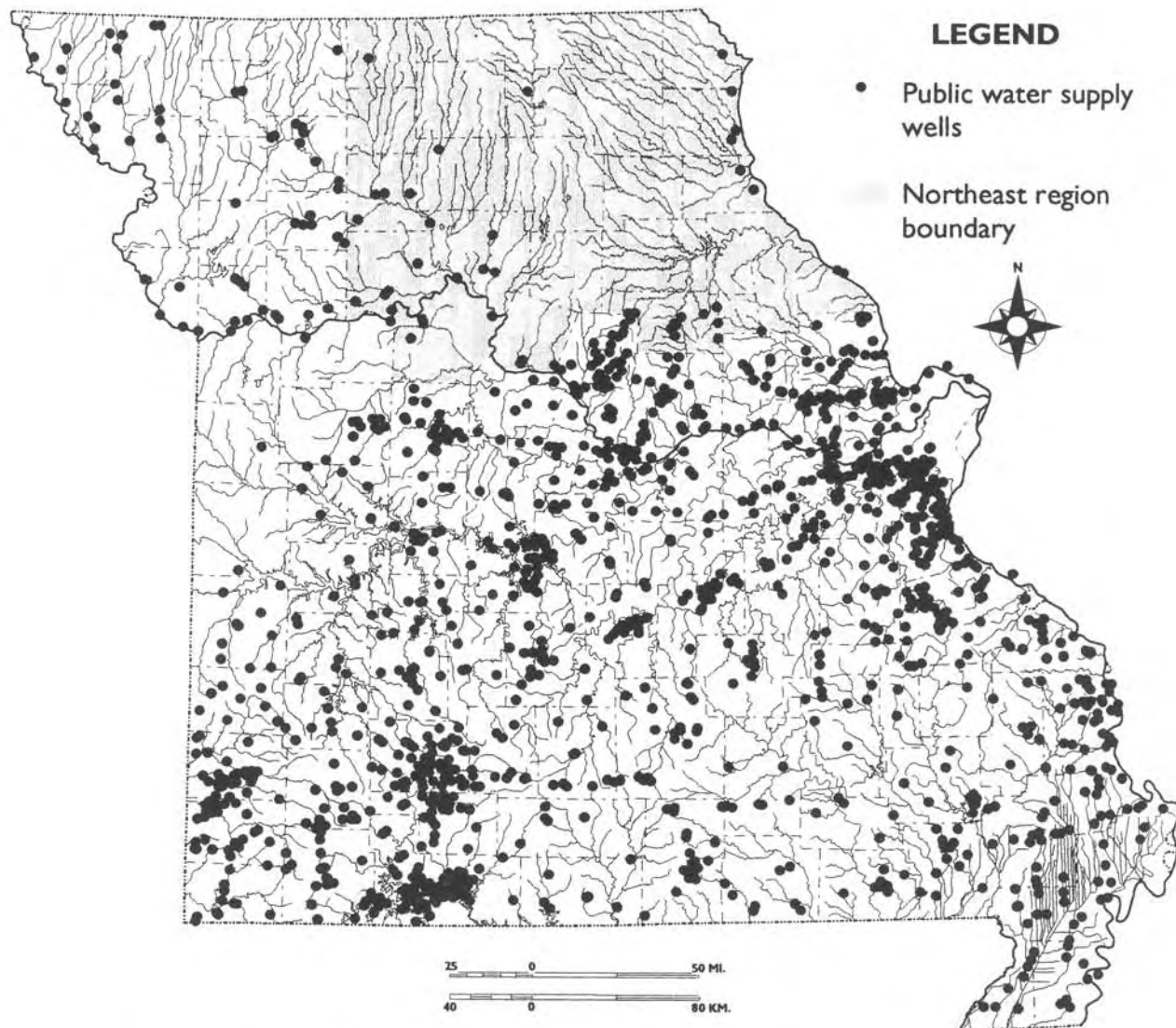


Figure 12. Locations of public water supply wells in Missouri (Source: Department of Natural Resources, 1996).

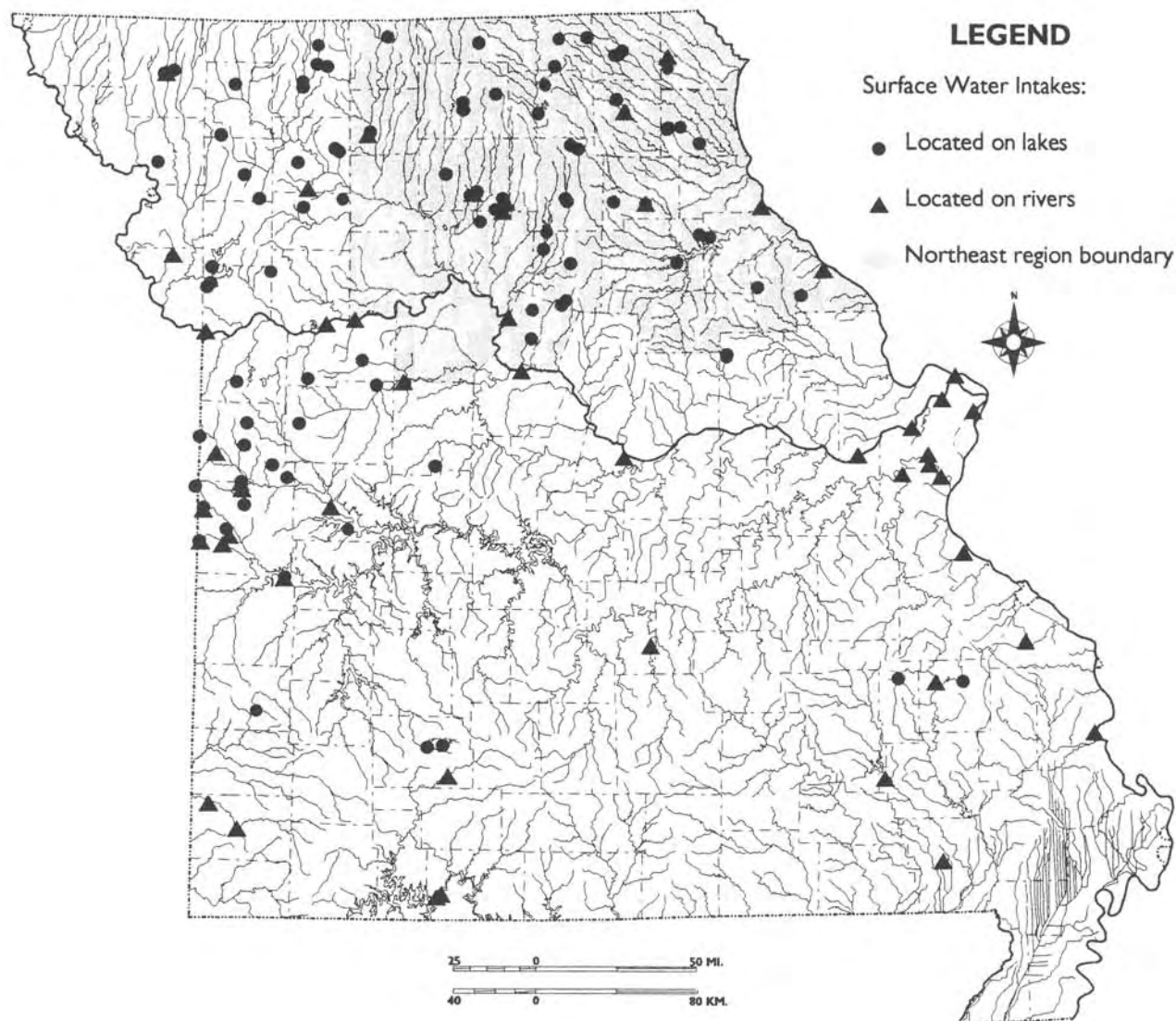


Figure 13. Locations of public water supply surface water intakes in Missouri (Source: Department of Natural Resources, 1996).

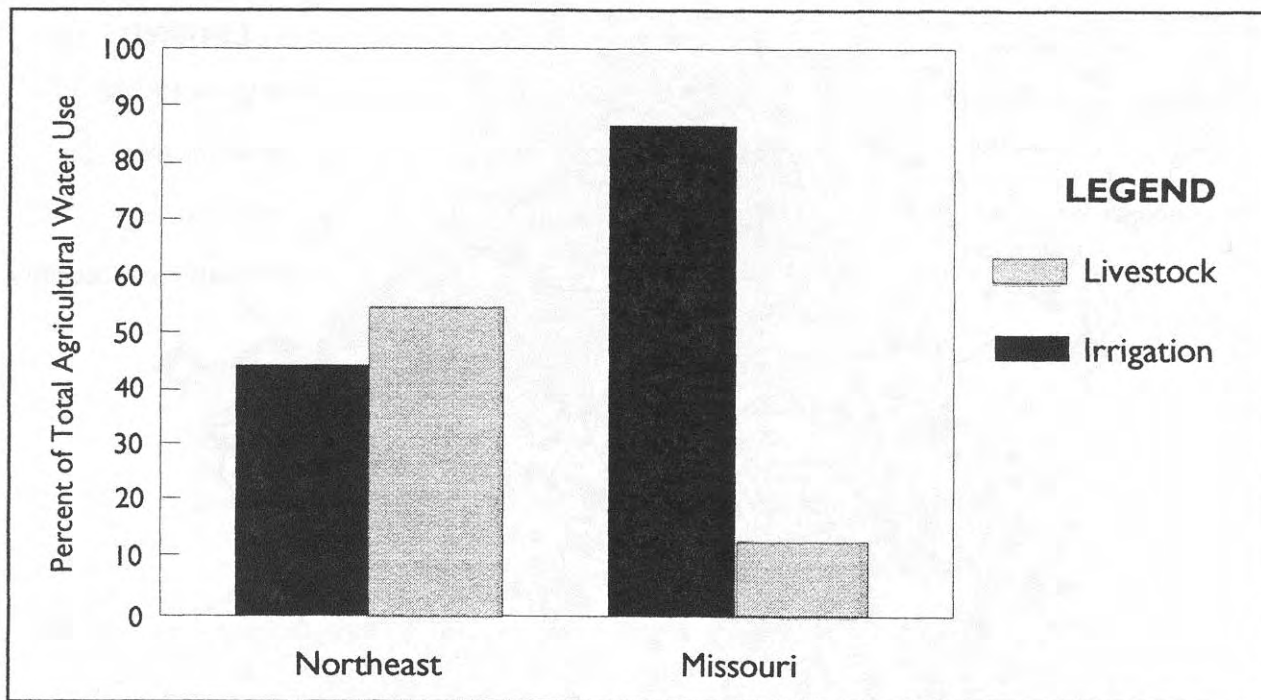


Figure 14. Comparison of agricultural water use in northeastern Missouri with statewide totals (Source: United States Geological Survey, 1990).

The Major Water Users Database of the Department of Natural Resources (DNR) estimated total thermoelectric power generation withdrawals at approximately 267 billion gallons of water in 1990. Withdrawals for thermoelectric power generation in northeastern Missouri come entirely from surface water sources. Although thermoelectric power generation requires large amounts of water it consumes very little of it. More than 99 percent of all thermoelectric power withdrawals were returned to their source waters. In northeastern Missouri, the Thomas Hill Energy Center operated by Associated Electric Cooperative Incorporated (AECI) is the predominant user of water for thermoelectric power generation, relying on water from Thomas Hill Reservoir for power plant cooling.

The U.S. Army Corps of Engineers operates a hydroelectric power generation facility at Clarence Cannon Dam on Mark Twain Lake (figure 4). The USGS estimated 1990 water use at the Clarence Cannon facility at slightly more than 257 billion gallons of water throughout the year. Hydroelectric power generation is usually considered a non-consumptive use of water, although a significant amount of water is evaporated annually from large impoundments. Clarence Cannon Dam, unlike AECI's Thomas Hill plant, generates power only during peak demand periods.

Instream Flow Uses

Fish and other aquatic organisms in northeastern Missouri's lakes and streams depend upon flowing water for survival and aquatic habitat preservation. Many municipalities in northeastern Missouri rely upon flowing water to safely release wastewater back into the environment. River barges on the Missouri and Mississippi rivers require flows sufficient to permit safe navigation. Swimming areas and boat launches found on nearly every body of water within the region accommodate recreational activities throughout most of the year. Although no water is withdrawn, each of these are "uses" of water as well. Collectively, these are often referred to as "instream" uses.

Recreational water use is one of the most visible "instream" uses. Several large lakes and reservoirs in northeastern Missouri provide numerous opportunities for recreation. Two reservoirs constructed by the U.S. Army Corps of Engineers, Mark Twain Lake in Monroe and Ralls counties and Long Branch Lake in Macon County, include recreation among their authorized purposes (figure 4). In 1994, Mark Twain Lake recorded approximately 18 million visitor-hours, the third highest total among Missouri's 13 Army Corps of Engineers reservoirs. Thomas Hill Reservoir, a privately owned reservoir constructed by AECI, primarily provides cooling water for the Thomas Hill Energy Center but also supports recreational activities (Vandike, 1995). Northeastern Missouri's rivers and streams (including the Missouri and Mississippi rivers) offer many recreational opportunities as well.

Preservation of aquatic life and habitat is another important "instream" use of water. Several wildlife refuges and conservation areas in northeastern Missouri maintain aquatic habitats: Fountain Grove Wildlife Area, Swan Lake Wildlife Refuge, Grand Pass Wildlife Area along the Grand and Missouri rivers, and the Ted Shanks Wildlife Area along the Mississippi River in Pike County. Most of northeastern Missouri falls within the Prairie Aquatic Faunal Region, although areas along the Missouri and Mississippi rivers are part of the Big River Aquatic Faunal Region (Pflieger, 1989). With the exception of the Missouri and Mississippi rivers, streams in northeastern Missouri are characterized by wide fluctuations in streamflow and extensive meandering. Streamflow during the late summer may be low or even nonexistent in upland drainages, although pools often hold water year-round, except during extended periods of drought. Despite characteristic low base flows, lowland drainages in the northeast have permanent streamflow that supports fish and wildlife throughout the year.

Many communities in northeastern Missouri release wastewater into nearby rivers and streams. In 1990, the USGS estimated that rivers and streams within the region assimilated 13.5 billion gallons of wastewater.



Water Use Problems

In this report, a number of discrete water use problems were identified by contributors from a number of state agencies, each providing a unique perspective on the water use problems faced in northeastern Missouri. Each description of the water use problems identified in this section follows a similar format. In each, a brief problem statement is followed by a short discussion in which background information is provided and the nature of the problem is established. It is important to note that the problem descriptions appearing in this section are not arranged according to priority or degree of severity.

Lack of Regional Water Planning and System Consolidation

Problem:

There is no overall, coordinated plan to link independent public water systems together. The current approach to water system consolidation is based on opportunity rather than advance planning.

Discussion:

Clean, abundant water has never been easy to find in northeastern Missouri. Bedrock geology in the area includes thick limestone formations in the eastern part of the region and thin limestones and shales towards the west, with some sandstone and coal beds at the surface. Bedrock is generally overlain by glacial deposits, including glacial drift and windblown silt deposits. These conditions are unfavorable for large volume, dependable groundwater resources, although sources in glacial drift can support limited water supply needs. In addition, groundwater in much of

the eastern parts of the region and much of the north is mineralized (figure 16). Northeastern Missouri has many municipal water supplies and public water supply districts (figure 15). Because groundwater resources are limited, many community public water systems in the region use water intakes on rivers and streams, or develop their own water supply reservoirs. Water emergencies are not uncommon during the summer because of dry weather and high demand.

As a result, statewide emergencies may pose serious problems. For example, an entire municipality might be without water because of drought, major contamination, equipment failure, or a combination of these. And drinking water standards continue to toughen. For example, federal standards for disinfection by-products, such as trihalomethane, will be reduced from 100 micrograms/liter ($\mu\text{g/L}$) to at most 80 $\mu\text{g/L}$ in the next few years, a change that systems throughout the region must face. Smaller systems often have a more difficult time meeting drinking water standards, making consolidation of systems desirable (Maley, written communication, 1997). Without interconnected water systems, statewide problems become much more difficult to resolve. And without comprehensive planning, no blueprint exists that would allow the unused drinking water reserves of Mark Twain Lake to be distributed to drought-prone areas during dry periods.

A potential problem in integrating water systems is a loss of autonomy perceived by constituents of small municipal systems. Although in many cases poor finances make integration desirable, some may feel more secure with the small systems they have built and are paying for, rather than investing in large systems over which they have relatively little control.

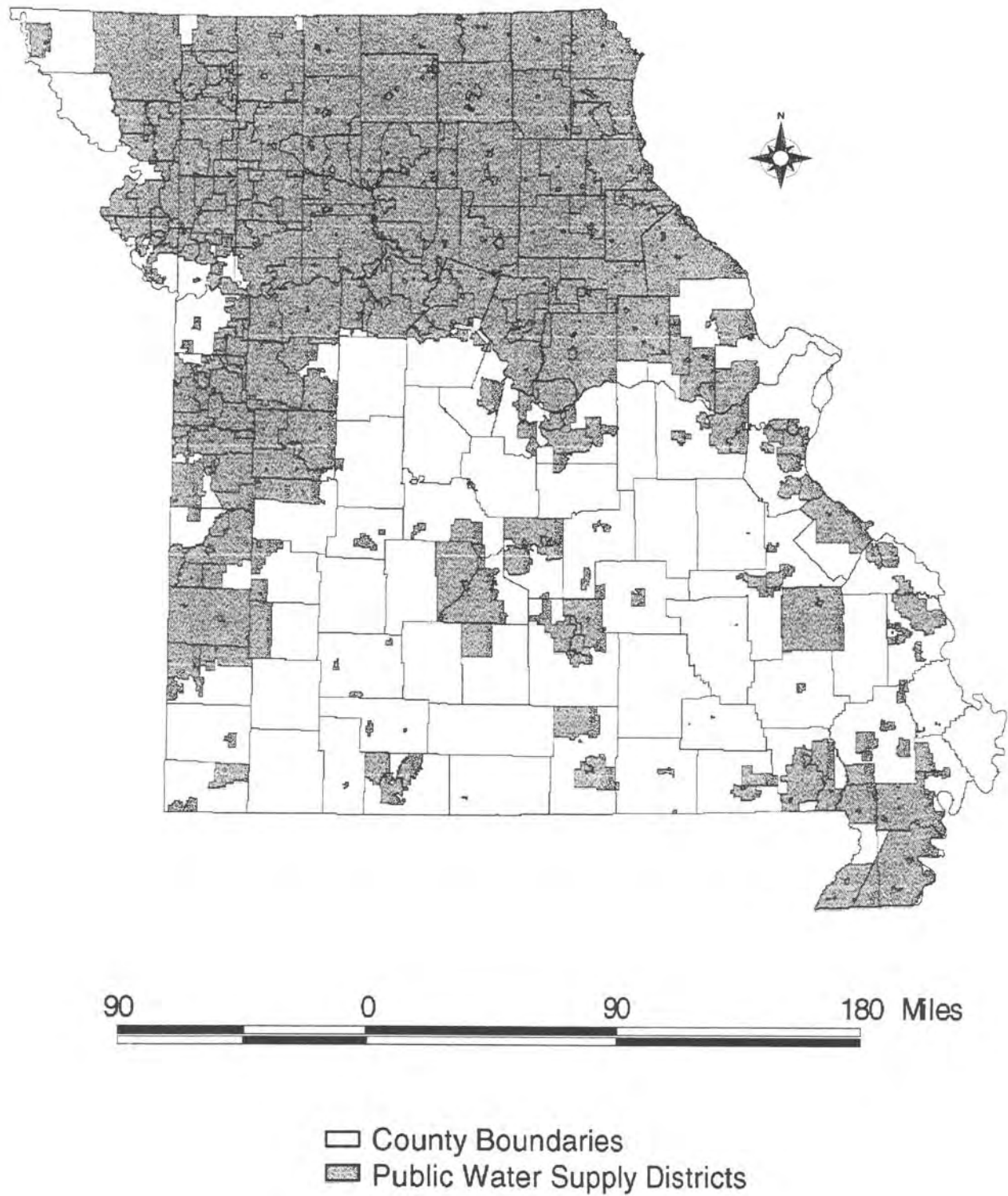


Figure 15. Public water supplies in Missouri (Source: Department of Natural Resources, 1997).

Lack of Model Contracts for Public Water Supply Systems

Problem:

Public water suppliers frequently enter into contractual agreements with other public water suppliers for a variety of reasons. Standard contracts have not been devised to help streamline this process, and often poorly written contracts between water suppliers contain language that is disadvantageous to one or both parties.

Discussion:

When communities throughout Missouri began developing public water supply systems to provide safe drinking water to their residents, rural water districts had not yet been created and the distance between towns made interconnection an unrealistic alternative. Therefore, most northeastern Missouri municipalities, even those with populations of only a few hundred people, developed community public water supplies. Depending on their locations and potential water sources, they constructed reservoirs, installed river intakes, or drilled wells to provide raw water, and built treatment plants to supply finished water.

Construction of many water supplies began before or during the Great Depression of the 1930s, when labor costs were relatively low. Rising costs of new supplies, and the need to replace outdated reservoirs and treatment plants, have made it difficult for many small northeastern Missouri communities to continue to supply water to their residents. They can no longer provide sufficient financial support for their water supplies, making interconnection with another supply desirable. The legal aspects of interconnection can, however, create difficulties for those involved. In the past, contracts between water suppliers have included terms unfavorable to one or both parties. Standardized contracts, which contain most of the necessary legal language and have been successfully used for other purposes, would include terms favorable to all, but have not been developed for agreements between water suppliers. Without standard contracts, struggling public water suppliers in northeastern Missouri may be reluctant to pursue inter-

connection with other supplies, despite the potential benefit.

Outdated Public Water Supply District Laws

Problem:

Legislation enacted several decades ago to allow formation of public water supply districts does not allow for the greater flexibility necessary to meet today's economic conditions.

Discussion:

Laws governing the formation and operation of public water supply districts are contained in Chapter 247 of the Revised Statutes of Missouri. The law divides public water supply districts into county districts and metropolitan districts. County public water supply districts are covered under RSMo 247.010 to 247.220. These laws were designed to allow the formation of public corporations to develop ample quantities of wholesome quality water to supply people in areas not served by municipal water supplies. Section 247.030 describes how the boundaries of the districts are to be established. The first sentence of this section states that "Territory that may be included in a district sought to be incorporated may be wholly within one or in more than one county, may take in school districts of parts thereof, and cities that do not have a waterworks system."

When these laws were passed, the language restricting the formation of county public water supply districts to areas other than cities having a waterworks systems may have been believed necessary to protect existing municipal water supplies from encroachment of their service areas. Many small communities may have feared that the new water districts might offer unfair competition to their municipal water systems, or take over operation of their systems. Today, however, two potential problems exist. First, many small municipalities may want neighboring public water supply districts to assume responsibility for supplying, operating, and maintaining their municipal system. They may even wish to sell their system to the water

district. This may be desirable because of the financial condition of the municipal water supply. Water districts can legally supply water to communities operating their own water systems, but under current law, the system itself must remain in the ownership of the municipal water supplier.

A second problem may exist where communities are surrounded or bordered by one or more county public water supply districts. In many places, the most profitable areas served by county public water supply districts are the unincorporated rural areas immediately adjacent to municipalities. Population densities in these areas are substantially higher than in more rural service areas, and there are greater numbers of service connections per length of water line. Chapter 247 contains language to allow public water supply districts to sell or transfer parts of their system to municipalities when the areas are annexed, but in many instances this can completely change the financial structure of water districts. Through annexation, a district can lose a high population density service area that helps defray the overall cost to the district. As a result, the district may have to substantially increase billing rates for other customers in the district. Thus, water districts may be reluctant to sell parts of their system. This can lead to competition between municipalities and water districts for new customers in annexed areas. In some cases, municipalities attempt to extend lines to serve industrial users beyond municipal corporate boundaries, into water supply district service areas. Litigation may occur as a result of this.

High Costs Associated With Developing, Expanding, and Replacing Public Water Supplies

Problem:

Many public water supplies serving small northeastern Missouri municipalities need expensive modifications or expansions that may be unaffordable to smaller, financially weak systems.

Discussion:

In much of Missouri, groundwater quantity and quality are adequate for public water supply. Most communities in southern Missouri use groundwater that requires little or no treatment. Often, it can simply be pumped from the well directly into the distribution system with no treatment at all. Except for the area south of the northern Audrain County line, groundwater use for public water supplies is limited (figure 16). Either the volume of groundwater necessary for a community water supply is inadequate, or the natural chemical quality of the water is too poor for use. For these reasons, most communities in northeastern Missouri rely upon surface water sources. A few communities, particularly those along the Mississippi River and the downstream reaches of a few of the region's larger streams, can use direct surface water intakes. Most streams in northeastern Missouri, however, do not have adequate dry weather flows to allow their use as raw water supplies during periods of drought. Therefore, most communities use surface water impoundments, storage impoundments filled by pumping water from streams, or both.

Surface water supplies are costly to develop. Surface waters typically contain fewer dissolved solids and have much lower hardness. However, surface water requires extensive treatment to disinfect, and to remove suspended sediments and other substances undesirable in a safe water supply. Microbiological contaminants, such as *E. coli*, cryptosporidium and giardia are of great concern. In addition, some agricultural and urban activities in the watershed can cause pesticide levels and nutrients to exceed maximum contaminant levels. As a result, treatment plants are expensive to construct and operate, and are likely to become even more so as federal drinking water standards become more stringent. In addition, reservoirs themselves are expensive to build and maintain, and must be periodically replaced.

Many northeastern Missouri communities, especially smaller towns with aging reservoirs and treatment plants, cannot afford to replace or extensively upgrade their facilities. Many of these communities have a high percentage of residents on fixed incomes, retired



Figure 16. Freshwater-salinewater transition zone.

ply cannot afford (or are unwilling to approve) a substantial increase in water rates. Rather than increasing rates, communities may pursue outside sources of funding for system improvements. At one time, there was considerable money available for water projects through various grants and low interest loans. Today, even when funds are available, some

communities lack the planning or engineering staff necessary to apply for them. For any of these reasons, many small municipal water supplies in northeastern Missouri face capital and operational costs they may be financially unprepared to meet, either now or in the near future.

Aging Infrastructure of Public Water Supply Systems

Problem:

The basic equipment, structures and installations public water suppliers use to provide services can become less efficient with age and undersized with increasing demand. Since much of the population of northeastern Missouri is served by public water supplies, problems associated with aging water supply infrastructure may need to be addressed in the future.

Discussion:

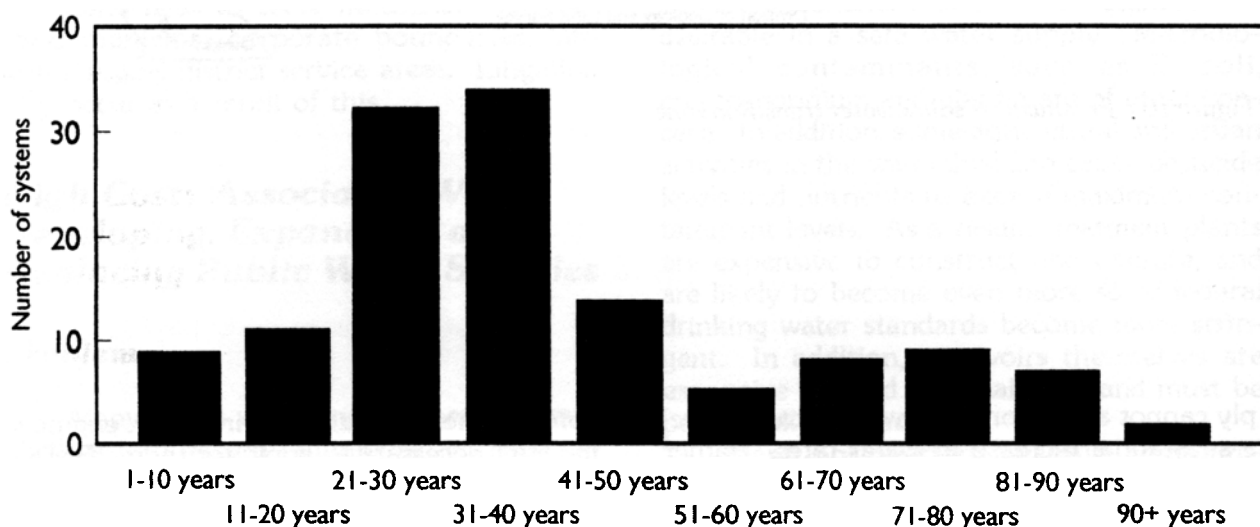
The National Water-Use Information Program of the USGS estimated that, in 1990, 81 percent of the population of northeastern Missouri was served by public water supplies. While the ages of municipal water supply systems and public water supply districts in northeastern Missouri range between 5 and 92 years, 50 percent of them are between 21 and 40 years old, and 10 percent of them are 75 years old or more (figure 17).

The problems caused by aging water supply infrastructures are many. Aging water lines made of materials inferior to those allowed by

current technology become fractured and begin to leak. Leakage, also called "transmission loss," reduces system efficiency and can have a negative impact on the system's revenue generation. This, in turn, may make it more difficult for the water supply system to finance much-needed improvements in the future.

Aging water supply infrastructures may also impact water quality. Outward leaking pipes also leak inward, allowing the system to become contaminated. In addition, service connections may have lead joints, which may leach lead into drinking water. In the human body, accumulations of lead and prolonged exposure to even very small amounts can result in serious health problems. Older systems may also have "dead-end" lines in which water may become stagnant and undrinkable.

Quite often, lines and facilities that were adequate when they were first constructed are undersized when it comes to present service requirements. With age, systems may no longer be able to convey the amount of water users need. Present household, industrial and public uses (such as firefighting and drought response) may be limited. Without viable alternatives, future development may also be restricted as potential users are discouraged from locating their facilities in a service region unable to support their needs.



(Source: Department of Natural Resources' Public Drinking Water Program)

Figure 17. Number of years in operation for municipal water supplies and public water supply districts in northeastern Missouri (Source: Department of Natural Resources, 1997).

Changing Water Requirements Stemming from Reversal of Long-Term Regional Population Trends

Problem:

The populations of several northeastern Missouri counties have increased since 1990, reversing a decades-long decline. Public water suppliers in the region may be unprepared to meet growing domestic and industrial water requirements.

Discussion:

The University of Missouri Office of Social and Economic Data Analysis (OSED) notes that northeastern Missouri was one of two rural regions in the state experiencing a pronounced change in population since 1990, compared with the 1980s. Census Bureau data indicates that a cluster of seven counties in rural north central Missouri (Mercer, Putnam, Schuyler, Scotland, Adair, Sullivan and Linn) all lost population in the 1980s, but have gained since 1990 (OSED, 1996). OSED also notes that "since the changes occurring in Missouri appear to be part of a national pattern it seems likely that the pattern of change during the past five years will continue through the rest of the decade."

Changing population growth patterns and economic trends can have a pronounced effect on local and regional water use. Most public water systems in northeastern Missouri serve relatively small populations. While existing facilities and infrastructure are able to support current usage levels, small public water supplies may be ill-equipped to meet the needs imposed by a growing population and, perhaps more importantly, increasing industrial/commercial water demand. The water requirements associated with economic growth may place additional strain on public water systems already burdened with meeting the domestic water requirements of a growing population.

Water Quality Threats in Watersheds

Problem:

Land use practices in a watershed can degrade water quality, impacting downstream users.

Discussion:

Water quality in northeastern Missouri's rivers, lakes and streams is closely tied to land use practices in a watershed. Urban development, agricultural practices, wastewater treatment, and other activities all affect water quality. The quality of water available to downstream users depends, to a large extent, on what occurs upstream. Upstream water users sometimes fail to consider the effects their land use activities have on water quality, impairing the quality of water supplied to downstream users.

A specific example of upstream practices that affect downstream users relates to public water supplies. As previously noted, groundwater suitable for use as drinking water is scarce in northeastern Missouri. Consequently, many communities in the region rely upon surface waters for their water supply. Runoff of herbicides and insecticides into surface waters used as drinking water supplies is a health threat, and increases the cost of treating drinking water.

Elevated concentrations of herbicides and insecticides often appear in raw, untreated water during the spring and summer following application of these chemicals to row crops. For example, the Environmental Protection Agency (USEPA) established a maximum contaminant level (MCL)⁶ of 3 parts per billion (ppb) for atrazine in drinking water in 1993. In 1994, 10 public water suppliers in Missouri were found to be operating out of compliance; three of these were in northeastern Missouri. Public water suppliers are required to remove herbicides to meet USEPA guidelines, which increases the costs of treatment. For atrazine, powdered activated charcoal (PAC) is the most commonly used treat-

ment. At least six public drinking water suppliers in northeastern Missouri have expended funds to remove atrazine from drinking water, spending between \$2,378 and \$16,832 in 1996 for powdered activated charcoal. Two of these facilities spent additional funds for upgrades to use PAC. In addition to the expense of treatment, environmental costs can be significant. Elevated concentrations of many herbicides and insecticides can result in reduced species richness and total abundance of insects, and can cause severe reductions in productivity, plant biomass, community structure (and have indirect effects on herbivorous invertebrates and fish) at high concentrations (USEPA, 1997). In May 1997, several streams in northeastern Missouri experienced potentially harmful concentrations of atrazine, including the Wyaconda and North Fabius rivers and Lick, Otter and Long Branch creeks (Smith and Sobba, 1997).

In nearly all cases, land activities within water supply watersheds are not controlled by downstream communities using those watersheds for their drinking water supply. As a result, activities that impair the utility of these watersheds for public drinking water supply may occur. Many times, little recourse is available to the community. In situations like this, the steps taken by a community to improve their water quality usually involve more stringent treatment, increasing the cost of finished water to consumers.

Current regulatory and incentive programs have improved water quality. However, so far, these programs have not eliminated all water quality problems that lower a supply's usefulness for all intended purposes. Recently, holistic approaches to watershed management have emerged, which bring together regulatory, incentive and educational programs to improve water quality. It is too soon to tell how effective these will be over the long run, and whether or not they will be effective in every watershed.

Water Requirements Associated with Industrial Growth

Problem:

On a regional basis, there are no mechanisms that are readily available to match industrial growth with areas that can best accommodate their water needs.

Discussion:

From an economic standpoint, most communities want new industry to move in, and those that are already there to expand. Some industries use more water than others. The amount of water used by industry in a region depends on the type of industry it is and the number of people it employs. For example, employees of a typical commercial establishment use approximately 50 gallons of water per employee per day, whereas those involved in the manufacture of dairy products⁶ may use more than 350 gallons of water per employee per day (Davis, et. al., 1988)⁷. Industries that are water-intensive (either in terms of sheer numbers of workers, or the amount of water used in production) may burden local water suppliers if located in a region without the water or infrastructure to meet their needs.

At present, some areas of northeastern Missouri do not have the water resources or distribution infrastructure needed to support water-intensive industrial growth. Much of the groundwater in northeastern Missouri is highly mineralized and of poor quality. In addition, many of the region's rivers and streams experience low flows between precipitation events and may run dry during drought. If inadequate water resources exist to meet the increased demand imposed by industrial growth, competition for water arises between existing and new water users. In northeastern Missouri, water shortages may not become apparent until the region experi-

⁵ The Missouri Safe Drinking Water Law defines Maximum Contaminant Level (MCL) as the "maximum permissible level...of a contaminant in any water which is delivered to any user of a public water system.

⁶ A water-intensive industrial group that includes establishments engaged in the manufacture (rather than production) of dairy products: creamery butter cheese, condensed and evaporated milk, ice cream and frozen dairy products. It also includes establishments processing (pasteurizing, homogenizing, vitaminizing and bottling) fluid milk for wholesale or retail distribution.

ences a drought. In the absence of proper drought planning, relatively drought-prone areas of rural northeastern Missouri may not be able to meet the needs of all users during dry periods.

In addition to water supply, northeastern Missouri soon may also face problems in water delivery. Some communities struggle to maintain the infrastructure necessary to meet current demands. Where infrastructure does not meet the needs of industrial growth, the cost of building infrastructure can be substantial. And building new infrastructure often adds time to the process, another prohibitive factor for a new or expanding industry.

Industrial Water Use Rights

Problem:

Some industries need large quantities of water to operate. Under Missouri's current water law, there is no guarantee that the necessary quantities of water will be available for use. Conflict resolution among competing water users is decided by the courts on a case-by-case basis, so outcomes are uncertain. This can have impacts on the long-range planning ability of industries and water availability for other users.

Discussion:

Missouri is a riparian water law state. A landowner adjacent to a river, stream, or other natural waterway has a legally protected right to a natural streamflow, except as changed by the reasonable uses of other landowners. This right guarantees a natural quantity of water in the waterway, as well as a natural water quality. Landowners along waterways likewise have the right to make reasonable use of the water. Under Missouri law, a business or company is afforded the same rights as an individual in these matters. The comparative reasonable use rule also applies to groundwater use. A landowner does not own groundwater, but owns the right to use the groundwater.

Water quality is protected under state statutes. No statutes, however, authorize any state agency to control the quantity and manner in which water is used. As a result, industries are free to use water in any manner they choose. When conflicts arise, the courts must decide comparative reasonableness on a case-by-case basis.

Statutory water law in Missouri covers many aspects of water resources. In general, however, Missouri's statutory law deals with water quality rather than how water can or cannot be used. The only law that deals specifically with the volume and manner in which water is used is the Major Water Users Law, RSMo 256.400. This law requires units of government, businesses and individuals with equipment capable of producing 100,000 gallons of water per day to register as major water users. The law, however, was passed for the purpose of gathering information rather than regulating water use. It does not allow government to ensure all riparian users the opportunity to make reasonable use of Missouri's water resources.

Local city governments have the authority to regulate municipal water use, and do when drought occurs. This authority, however, does not extend to the state. Although the Governor has power to regulate water use and distribution during a state of emergency, the State of Missouri, under existing law, has no practical authority to regulate the quantity of water used or the manner in which it is used. In parts of Missouri, especially during prolonged drought conditions, the demands placed on water resources may exceed the natural capacity of the river, stream, or aquifer. Without regulatory authority, only the judicial system has the legal authority to decide water use disputes. Cases often must be decided by judges who already have full dockets. In many cases, it may take months or even years for a civil suit dealing with a water supply issue to be heard. In addition, litigants may not have the financial resources necessary to pursue such a civil suit, leaving disputes unresolved. This has the effect of prolonging conflicts between competing users (and any damages incurred as a result). During drought, the

⁷ Water use coefficients used are generalized estimates of use applicable nationwide, rather than specific figures determined for use in northeastern Missouri.

consequences of an extended conflict between water users can become serious.

Abandoned Pre-law Coal Mines

Problem:

Acid water discharges are associated with abandoned coal mining land. These discharges degrade streams and lakes, making them unsuitable for uses such as aquatic habitat, agriculture, and drinking. The estimated cost for reclaiming abandoned mine lands greatly exceeds the amount of money that is currently available for that purpose.

Discussion:

Most of Missouri's coal reserves are located in a wide band extending from north central Missouri to the southwest portion of the state (figure 18). Missouri was a major coal mining state for more than 100 years. From the first coal mining in the 1840s until March 28, 1972 (the effective date of Missouri's first strip mine legislation), more than 67,000 acres of strip-mined lands were abandoned without reclamation by mining companies. When water moves through old mine shafts, or the rock layers that are associated with the coal seams are exposed, they undergo a weathering process. The result of this weathering process is acid mine drainage, which occurs when groundwater leaches sulfur in the coal and shale to produce sulfuric acid. Acid mine drainage can be highly acidic and commonly contains elevated levels of iron, manganese and other heavy metals. Acid mine drainage that originates in unreclaimed abandoned coal mine lands has made portions of streams in western and northern Missouri lifeless for decades.

Abandoned mine land reclamation took a giant step forward in 1977 when the U.S. Congress enacted Public Law 95-87, the Surface Mining Control and Reclamation Act of 1977 (SMCRA). Title IV of SMCRA establishes the Abandoned Mine Land (AML) program that provides for the restoration of eligible lands and waters mined and abandoned or left inadequately restored. In January 1982, Missouri received approval from the Office of Surface Mining to operate the aban-

doned mine land program and to conduct reclamation work in the state.

Public Law 95-87 requires that Missouri's Abandoned Mine Land program reclaim the higher priority abandoned coal mine sites before addressing problems created by mining other commodities. Therefore, the Abandoned Mine Land program presently addresses only problems caused by coal mining. The order in which most abandoned mine land is reclaimed is determined by classifying the land into one of three categories.

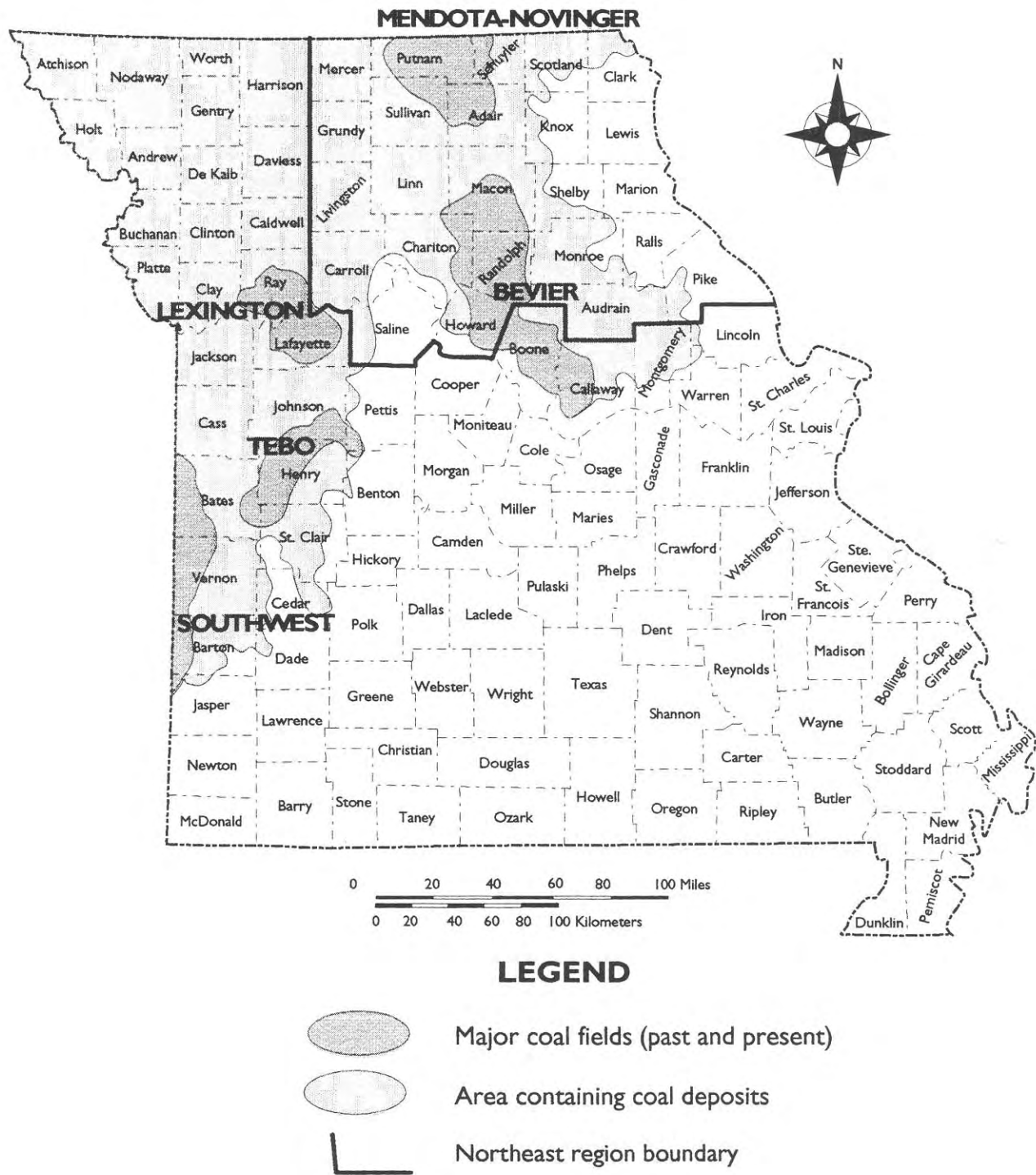
Priority I--The protection of public health, safety, and general welfare from extreme danger resulting from the adverse effects of past coal mining practices;

Priority II--The protection of public health, safety, and general welfare from the adverse effects of past coal mining practices that do not form an extreme danger;

Priority III--Restoration of land and water resources and the environment previously degraded by the adverse effects of past coal mining practices.

Health and safety problems (Priority I and II) include dangerous piles of mine refuse and embankments, burning coal refuse, highwalls, subsidence, open shafts, hazardous mining facilities, and polluted water used for agricultural and human consumption. Environmental problems (Priority III) include bare acidic spoils and coal refuse areas that pollute water through soil erosion, sedimentation, and acid mine drainage.

The Abandoned Mine Land program is funded by a federal tax on coal. The U.S. Office of Surface Mining Enforcement and Reclamation (OSM) collects 35 cents a ton on surface mined coal, 15 cents a ton for coal mined underground and 10 cents per ton of lignite mined. Money collected from coal mining is deposited into the Abandoned Mine Land Reclamation Fund and then distributed to states to reclaim eligible abandoned coal mine lands. When Congress passed SMCRA, it realized that AML fees would not generate enough revenue to address every potentially eligible site, and left to the states and Indian tribes the hard choices of which projects to select for funding using specific criteria.



(Source: Robertson, 1973)

Figure 18. Major coal fields and areas of coal deposits in Missouri.

As of June 1996, the Missouri Abandoned Mine Land program has received nearly \$56.3 million in federal support from the AML fund. However, because of declining coal production, Missouri's allocation has decreased. Since 1987, the U.S. Congress has included a minimum base funding amount in the abandoned mine land appropriation to allow the states with significant coal mine problems but limited coal production to continue their program. Although Missouri received an annual allocation of \$2.0 million for fiscal year 1994, its fiscal year 1995, '96 and '97 allocations have been reduced to \$1.5 million.

Also, in order for a state to receive AML Title IV funds, it must maintain an adequate Title IV regulatory program for coal mining. Because of sharply declining coal production and a loss of program funding through permit fees, Missouri faces the possibility of an inadequate regulatory program. This would result in the loss of all AML funding.

Although nature has reclaimed much of the land adequately over the years, reclamation work must still be completed to correct a range of public health, safety, and environmental problems. To date, 214 problem areas, totaling over 11,500 acres have been identified as posing a threat to the public health, safety, or environmental quality. Completed reclamation projects, along with those under construction, total more than \$34,874,000 in reclamation costs. Missouri's current AML inventory contains \$75,576,172 of Priority I and II problems. Therefore, approximately 46 percent of Missouri's high priority sites have been reclaimed. Even so, approximately \$41,000,000 of Priority I and II abandoned mine land problems have yet to be reclaimed in Missouri, some of which can be found in northeastern Missouri.

Wastewater Assimilation by Streams

Problem:

Streams in northeastern Missouri often have very low base flows, which limit the capacity of streams to assimilate wastewater discharges. Low wastewater assimilation capacities increase the likelihood that a stream will be impacted by wastewater discharges. They

also increase the level of treatment necessary to maintain streamflow at acceptable water quality standards.

Discussion:

Millions of gallons of wastewater are discharged into northeastern Missouri's rivers and streams every day. In 1990, the United States Geological Survey estimated wastewater returns in the region at approximately 13.5 billion gallons (USGS, 1997 [Online]).

For several reasons, rivers and streams in northeastern Missouri have relatively poor wastewater assimilation capacities. Many rivers and streams in the region experience markedly low flows between rainfall events. In addition, many of northeastern Missouri's streams are characterized by muddy or sandy beds and relatively few riffle-pool sequences, both of which reduce assimilative capacity (Decker, personal communication, 1997). These conditions can make it more difficult for treatment facilities to meet water quality standards. Low flow conditions lead to increased requirements for better wastewater treatment. In some cases, the only flow in some receiving streams is wastewater effluent from upstream discharges (Decker, personal communication, 1997).

Moderately high levels of dissolved oxygen are necessary for the preservation of healthy aquatic ecosystems (Dunne and Leopold, 1978). Even under pristine conditions, microbial organisms (mainly bacteria) consume substantial amounts of dissolved oxygen decomposing organic debris such as leaves and animal waste. When wastewater is released into a stream, breaking down the organic matter within it imposes an additional demand on the stream's supply of dissolved oxygen. Stream width and turbulence influence the rate at which dissolved oxygen is replenished in streams and rivers (Dunne and Leopold, 1978). As discharge falls, stream width and turbulence decrease as well, leading to lower reaeration rates and reduced levels of dissolved oxygen (figure 19). During low flow periods, the demand for dissolved oxygen may exceed supply and dissolved oxygen levels in the stream may fall below the amount required to support fish and other forms of aquatic life.

Elevated concentrations of chemical compounds such as phosphates, nitrates and ammonia are often found in wastewater. While harmful to aquatic ecosystems at high concentrations, these compounds may be successfully diluted in streams having adequate discharge. However, when released into streams experiencing low flows, sufficient dilution may not occur. Phosphates and nitrates provide nutrients for plant growth in streams receiving wastewater discharges. High concentrations of these compounds can contribute to the eutrophication of lakes and streams receiving wastewater. Commonly, elevated concentrations of plant nutrients are linked to algal blooms, which impair water quality in a number of ways. Algal blooms often discolor water and lead to undesirable tastes. When algal blooms die off, the ensuing decomposition contributes to the oxygen demand being placed on the receiving water. As noted above, fish and other aquatic species may be killed as a result. In addition, these compounds are toxic to fish and other aquatic life, and can lead to fish kills and destruction of aquatic habitat if found in elevated levels. If not diluted below toxic levels, they may threaten human health as well.

Wastewater treatment facilities also rely upon adequate streamflow to dilute the concentrations of trace metals sometimes occurring in wastewater releases. While essential for plant and animal growth, high concentrations of trace metals can be very toxic. Even at relatively low concentrations, trace metals can harm aquatic ecosystems. Human consumption of water contaminated by trace metals can likewise have serious health effects. During dry periods, streamflow may not be sufficient to dilute concentrations of trace metals to acceptable levels.

Impacts of Concentrated Animal Feeding Operations on Northeastern Missouri's Water Resources

Problem:

Large-scale concentrated animal feeding operations (CAFOs) have developed in many areas of the state, including northeastern Missouri. With their growth, water quality problems associated with manure management

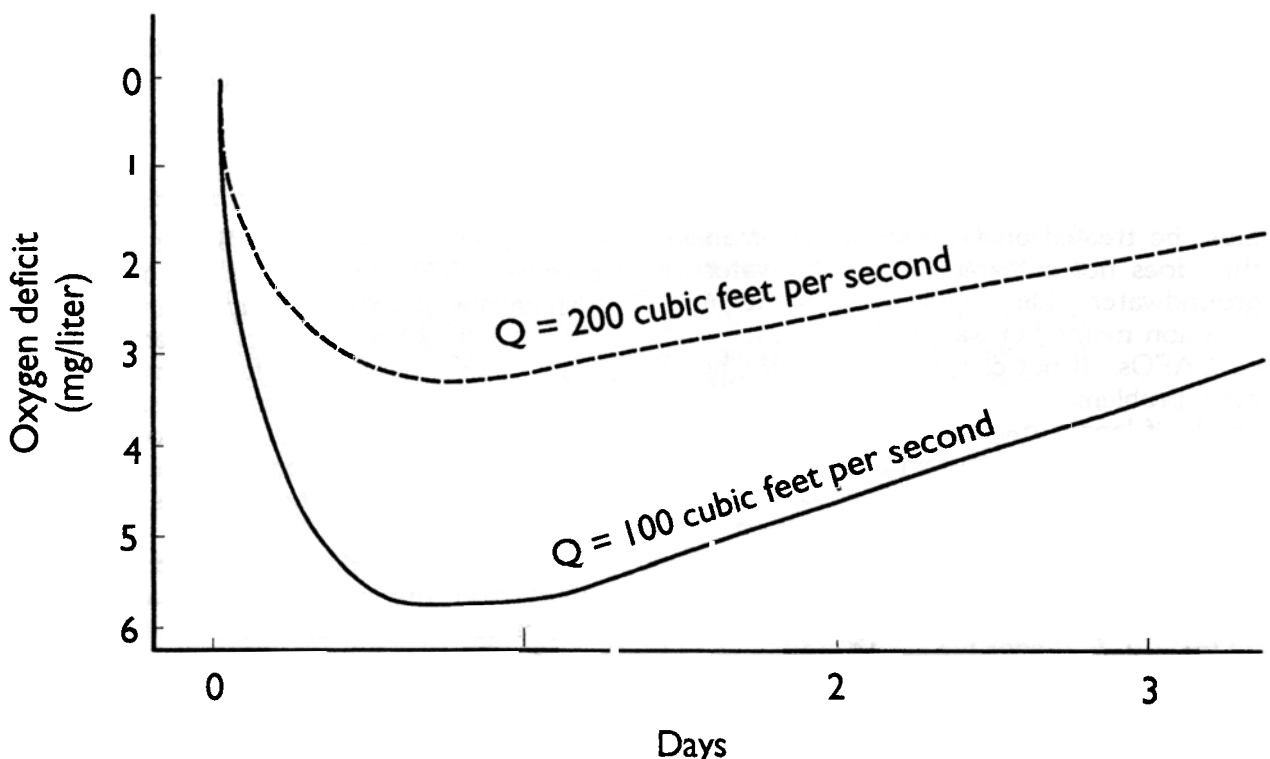


Figure 19. Effects of low streamflow on dissolved oxygen level (after Leopold and Dunne, 1978).

have arisen. Manure management deficiencies associated with these operations have led to water quality problems. If the number and size of CAFOs continue to grow without accompanying improvements in waste treatment technology and management, the potential for further water quality problems may increase.

Discussion:

In northeastern Missouri, there are approximately 42 Class I CAFOs and 579 Class II animal feeding operations (AFOs). A Class I CAFO has at least 1,000 animal units, and a Class II AFO has between 300 and 1,000 units. One animal unit is equal to 1 beef cow, 0.7 dairy cow, or 2.5 hogs. The water in deep, high-yield groundwater aquifers north of the fresh-water-salinewater transition zone (figure 20) is too highly mineralized to be of acceptable quality for CAFOs, and shallower, less productive aquifers in the region may not be able to supply them with sufficient quantities of water. As a result, surface water impoundments are typically used. In some cases, however, there have been problems in maintaining streamflow below large CAFO impoundments, and minimum flow requirements have been added to some of the permits which authorize these dams.

In addition to localized water supply issues, water quality concerns have arisen as well. CAFOs can generate large volumes of waste and wastewater. A great deal of the water used in CAFO operations becomes wastewater that must be treated or disposed of in a manner that does not contaminate surface water or groundwater. Land application is the most common method of wastewater disposal used by CAFOs. If not carried out properly, however, problems can be experienced. For example, if land surface waste application takes place shortly before a major precipitation event, waste may be carried from the application areas into streams. Waste may be used as a crop nutrient. And if done in excess of crop needs, land application of these nutrients can result in their migration into nearby streams. An additional water quality problem associated with CAFOs is related to failures in wastewater handling systems, such as spills from pipeline breaks.

Increased nutrient loading in streams from animal waste causes chronic problems such as increased algal growth, fluctuating oxygen levels, reduced invertebrate populations, and can result in the decline of some fish species. Spills related to system failures can cause fish kills and other environmental problems. The 1996 Missouri Water Quality Report lists improper application and spills of hog manure as existing water quality problems in portions of northern Missouri.

Recent legislation addresses some of these concerns. RSMo 640.700, commonly known as the "Hog Bill," establishes Department of Natural Resources jurisdiction and authority to regulate the establishment, design, permitting, construction, operation and management of Class I CAFOs. In addition, CAFOs are defined as point sources of water pollution in the Missouri Clean Water Law (RSMo 644), and are subject to all permitting, design and water quality regulations promulgated under that law.

Livestock Watering in Drought Conditions

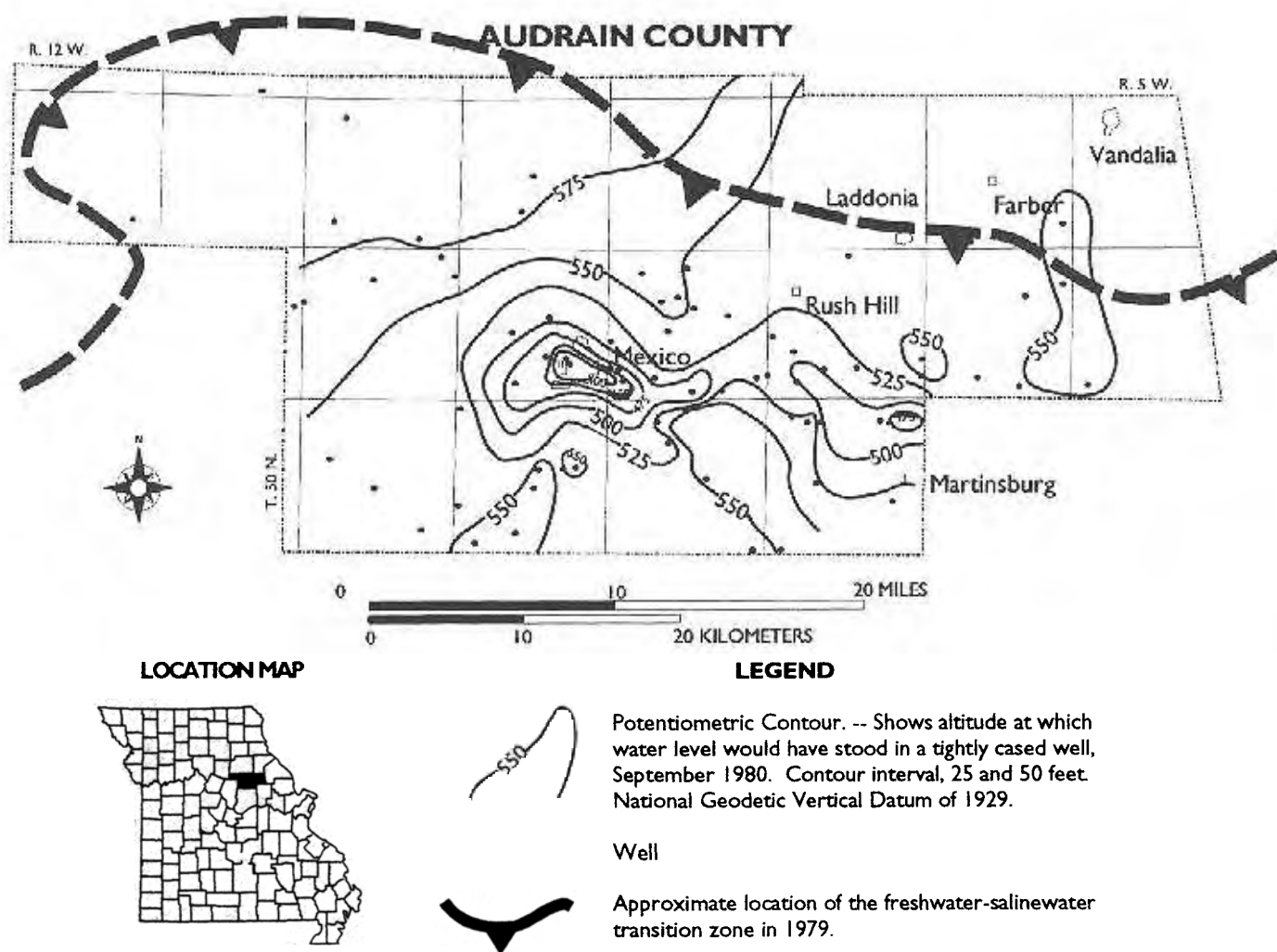
Problem:

During extended dry periods, shortfalls in water availability occur which can impact livestock watering.

Discussion:

In 1990, the United States Geological Survey (USGS) reported the use of 11.81 million gallons of water per day for animal watering in northeastern Missouri. Seventy-five percent of the water used for animal watering comes from surface water sources. In the region, the quality of local deep groundwater is generally less suitable for agricultural uses than surface water sources because it is highly mineralized.

Lacking significant, sustained streamflow, runoff from precipitation is virtually the only source of surface water in northeastern Missouri. As a result, streamflow throughout the region is widely variable. During dry periods, watercourses with little or no streamflow are relatively common. Therefore, areas not close



Groundwater exists beneath the surface of the earth in two major environments: unconfined and confined aquifers. In unconfined conditions, the water table is free to rise and fall, and the water table is subject to atmospheric pressure. During periods of drought, the water table falls. When precipitation begins again, aquifer recharge is generally rapid. In confined conditions, the rock structure isolates the water from atmospheric pressure. The elevation to which water rises in a well that taps a confined aquifer is called its potentiometric level. The potentiometric surface is an imaginary surface (analogous to a water table), representing the confined pressure at the top of the aquifer. Source: Driscoll, Fletcher G., *Groundwater and Wells*, St. Paul: Johnson Division, 1986, pages 62-65.

Figure 20. Potentiometric map of the Cambrian-Ordovician aquifer, September 1980, and approximate location of the freshwater-salinewater transition zone in 1979. Groundwater in the Cambrian-Ordovician aquifer south of the line generally contains less than 1,000 mg/l total dissolved solids. (Sources: Emmett and Imes, 1984, and Emmett and Knight, 1979).

to the region's larger rivers and without a suitable source of groundwater can only rely upon stored streamflow, primarily from runoff events. The necessity of reservoirs in northern Missouri is widely recognized. For example, Skelton (1966) noted that "storage reservoirs are required in most cases for effective utilization of surface water supplies." Consequently, impoundments play an important role in meeting the water needs of northeastern Missouri.

A pond inventory conducted by the Missouri Department of Conservation in 1977 estimated that there were 5.7 ponds per square mile in northern Missouri. This figure, if applied to northeastern Missouri, equates to 77,000 ponds throughout the region. Most of these impoundments are one acre or less, and are used almost entirely for livestock watering. Unfortunately, they are susceptible to drought and may not be a reliable source of water in extended hot, dry weather.

In past droughts, finding water for livestock has created emergency conditions. One source of water has been "custom irrigation operators." These enterprises set up pumping stations to distribute water to willing buyers. Using these water suppliers can be expensive. This alternative is probably not cost-prohibitive compared to selling off the herd, however, which is the fate of some livestock producers during extended droughts. Emergency livestock water operations have also tapped public water sources. These operations also are costly and may not be readily available, especially during prolonged episodes of drought.

Long-term, cost effective, strategic measures are needed to deal with shortfalls in water supply for livestock watering purposes.

Aquifer Depletions in Audrain County

Problem:

Agricultural irrigation in Audrain County may be contributing to groundwater-level decline in the Cambrian-Ordovician aquifer. Lowering of groundwater levels could induce poor quality groundwater in extreme northern and northeastern Audrain County to move to the

south into areas where the aquifer currently contains freshwater.

Discussion:

The natural quality of groundwater from deep bedrock aquifers varies greatly in northeast Missouri. Audrain County is the most northerly county in this region where groundwater in the Cambrian-Ordovician aquifer is generally potable. All public water supplies in Audrain County use groundwater. Also, rural residents, businesses, and farms use groundwater to supply most of their water supply needs, including agricultural irrigation.

The freshwater-salinewater transition zone (figure 20) traverses northeastern Missouri through the northern tip of Boone County, roughly parallels the northern border of Audrain County, except in the northeastern part of the county where it trends to the southeast passing near Laddonia, and bisects Pike County, passing near Bowling Green. South of the transition zone, water in the Cambrian-Ordovician aquifer generally contains less than 1,000 mg/L total dissolved solids, while north of the line dissolved solids, chloride, and sodium increase dramatically.

The Cambrian-Ordovician aquifer in northeast Missouri contains essentially the same geologic formations as the Ozark aquifer in the Salem and Springfield plateaus. Yields of wells that penetrate the aquifer can be as high as 1,200 gallons per minute. A shallower aquifer, composed of Mississippian-age limestone units, overlies the Cambrian-Ordovician aquifer. The two aquifers are separated by low-permeability Silurian and Devonian sedimentary rock units that form an aquitard. The Mississippian aquifer has adequate yields for domestic purposes, but cannot supply the volume of water necessary for agricultural irrigation or for municipal water supply (figure 21).

The City of Mexico is the largest user of groundwater in Audrain County. Mexico's water is supplied from five wells drilled into the Cambrian-Ordovician aquifer. The system is owned and operated by a private company, the Missouri-American Water Company. Missouri American currently produces an average of about 2.1 million gallons of water per day. The wells at Mexico not only supply the

city, but also supply Audrain County Public Water Supply Districts 1 and 2. In 1995, Missouri-American Water Company at Mexico pumped 718 million gallons of water from the Cambrian-Ordovician aquifer. In the mid-1970s, several farmers in Audrain County began constructing additional deep wells to supply center pivot irrigation systems. In 1979, 18 irrigation wells were known to exist in Audrain County. As of 1995, 19 registered major water users were reporting irrigation withdrawals from 21 wells. The 1995 reported groundwater use for irrigation in Audrain County was approximately 459 million gallons.

Water level data collected by the USGS (Emmett and Imes, 1984) also show that irrigation in the late 1970s caused seasonal pumping cones to develop in the irrigation areas of

Audrain County. Groundwater modelling by the USGS at that time indicated that by the year 2000, the potentiometric surface would decline 10 to 25 feet with no groundwater use for irrigation, and 40 to 80 feet with groundwater-supplied irrigation.

The USGS continued to collect groundwater-level data from about 50 farm and irrigation wells in Audrain County through the 1980s. These same wells were measured again in 1997 by the USGS and DGLS, and their values compared to earlier measurements. To illustrate the magnitude of drawdown in the area, fall 1997 water levels were compared to water levels measured during fall 1979 (figure 22). These data indicate an overall water-level decline between 1979 and 1997, but not as significant a decline as that predicted by the

USGS model. The greatest water-level decline is in the Mexico area, where water levels have declined between 50 and 100 feet. West of Mexico is an area where the 1979-1997 decline is from 40 to 50 feet, and northwest of Mexico the decline is 30 to 40 feet, as is a small area south of Vandalia. Most of Audrain County had only 20 to 30 feet of water-level decline between fall 1979 and fall 1997.

Groundwater is still used for irrigation in Audrain County, but few additional irrigation wells have been drilled during the past several years (Sobba, personal communication, 1997). Although the volume of groundwater used for irrigation has been relatively stable in Audrain County for the past several years, water use by Mexico and the rural water districts in Audrain County has increased and probably will continue to do so. Over time, the drawdown cone in the Mexico area may induce movement of mineralized groundwater from north of the freshwater-salinewater transition zone to areas in the aquifer that formerly produced freshwater. In addition, deeper groundwater levels will increase the pumping costs of all groundwater users.

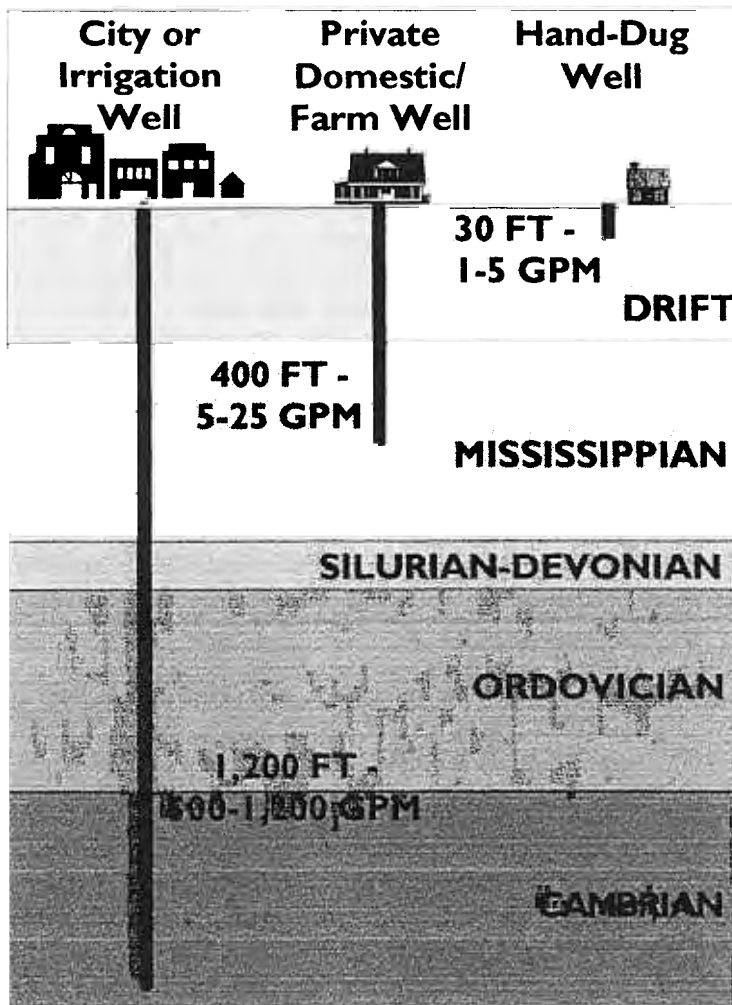


Figure 21. Well yields from aquifers in northeastern Missouri, in gallons per minute.

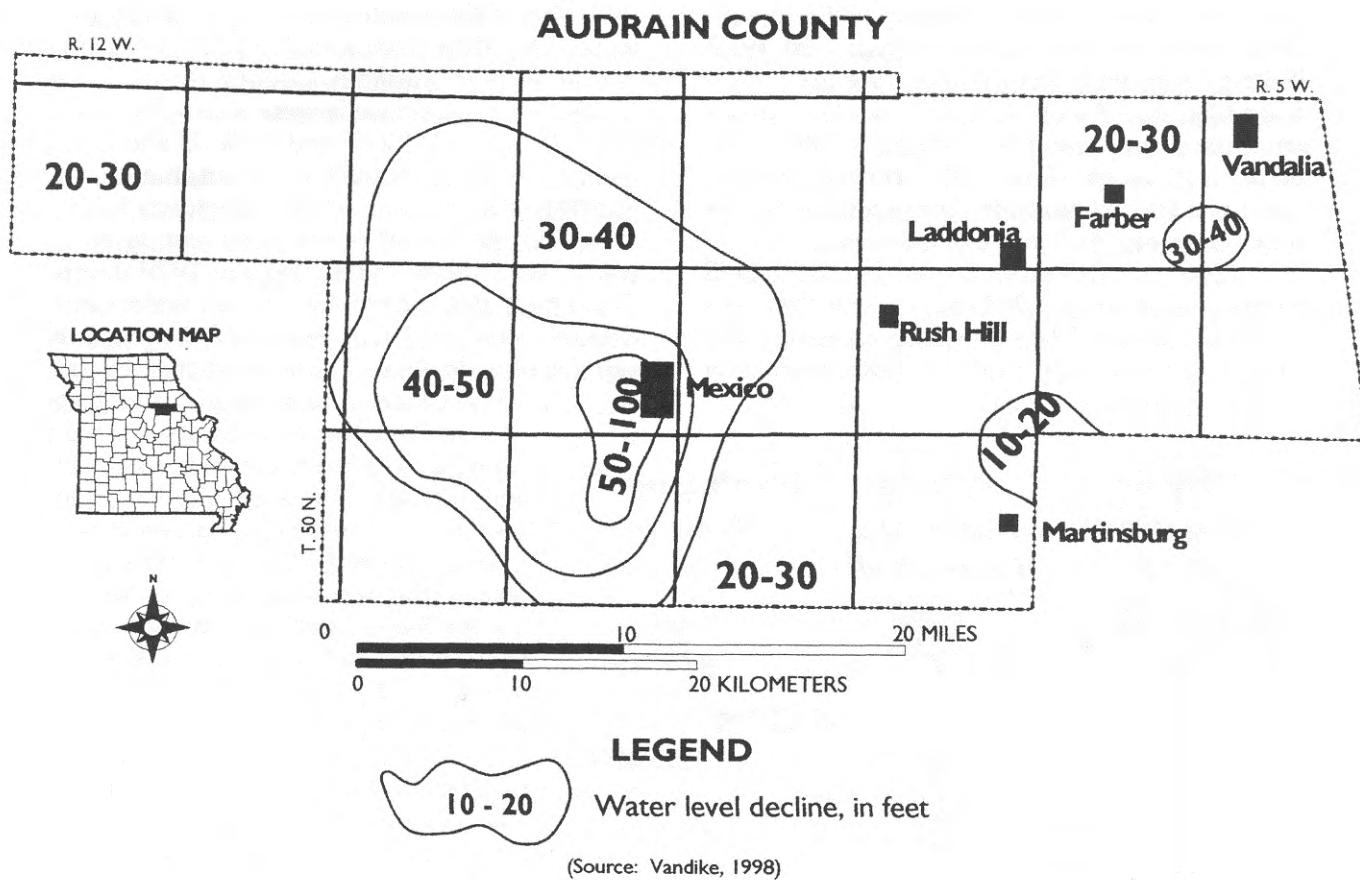


Figure 22. Generalized groundwater level decline in Audrain County, October 1979 to October 1997.

Lack of Hydrologic Data

Problem:

Critical water resources data are inadequate and unavailable, affecting our ability to effectively and efficiently utilize water to meet our needs.

Discussion:

It is estimated that there are approximately 56,000 miles of rivers and streams in the state (MDC, undated), but flow data are collected and published for 109 gaging stations, only 28 of which are located in northeastern Missouri (USGS, 1997). The majority of these stations are located in the eastern and southeastern counties of the region. Stream gaging coverage is very sparse in the northern counties. In addition, 29 stream gaging stations within the region established in the past have been discontinued (figure 23). The water quality monitoring network is designed to collect data that will meet water quality management and planning needs, but there are only 58 monitoring stations statewide in this network (USGS, 1997). Of these, only three are in northeastern Missouri. Nine previously established water quality stations have been discontinued.

Missouri has a land area of 69,709 square miles, under which lie an estimated 500 trillion gallons of water in aquifers (Miller and Vandike, 1993). However, the groundwater monitoring network has only about 50 wells equipped with automatic data recorders to characterize the location and availability of groundwater statewide, and only four in the northeast region (DNR/DGLS, 1996).

The Palmer Drought Severity Index (Palmer, 1965), the most commonly used drought indicator, divides all of Missouri into only six regions. Ten counties of northeastern Missouri fall into region one, the remainder into region two (figure 24). Drought in Missouri is often characterized on the basis of these regions, a generalization that fails to consider localized drought conditions. Approximately 2,700 public water supply systems serve the citizens of Missouri (DNR/DGLS, 1999 *Water Resources Law Annual Report*), a large number of which operate in northeastern Mis-

souri. Seventy-one public water supply reservoirs are located in northeastern Missouri (figure 25). There is no uniform data collection program to estimate water availability for these systems or reservoirs.

In some instances, the data used in water resources decision making are not current. Scientists believe that climate is changing. They also recognize that weather follows cyclic patterns that affect the amount of water available and the amount we need, especially in hot, dry periods when demand is greater. These two factors create a "moving target" of continually changing conditions. Without current data, it becomes difficult to follow the target, impairing analysis and prediction efforts.

Inadequate data collection may affect the future development of public water supplies in northeastern Missouri. It is important to design water systems that will meet the needs of a community without overdesigning it and increasing construction costs. Dependability is a crucial component of water supply design. Running out of water can be quite costly for a community. However, an overdesigned water system based on inadequate water data also places an unnecessary financial burden on the community it was constructed to serve. Inadequate water data also makes it difficult to design, refine and improve water conservation programs implemented by water systems to mitigate the effects of drought conditions. Water quality issues also limit the design and development of public supplies utilizing surface water. Special studies, which can be quite costly, may be required to determine whether or not certain contaminants or constituents are present in water that might affect its use as a water supply. Insufficient data can be a detriment to the proper operation and maintenance of public water supplies.

Many federal regulations are aimed at maintaining water quality and sustaining the environment. Among them is the National Pollutant Discharge Elimination System (NPDES), which regulates point-source pollution. Rivers commonly have many permitted discharges along their courses. Inadequate or unavailable water data can make it difficult to determine the impact of any given NPDES discharge on the receiving water body.

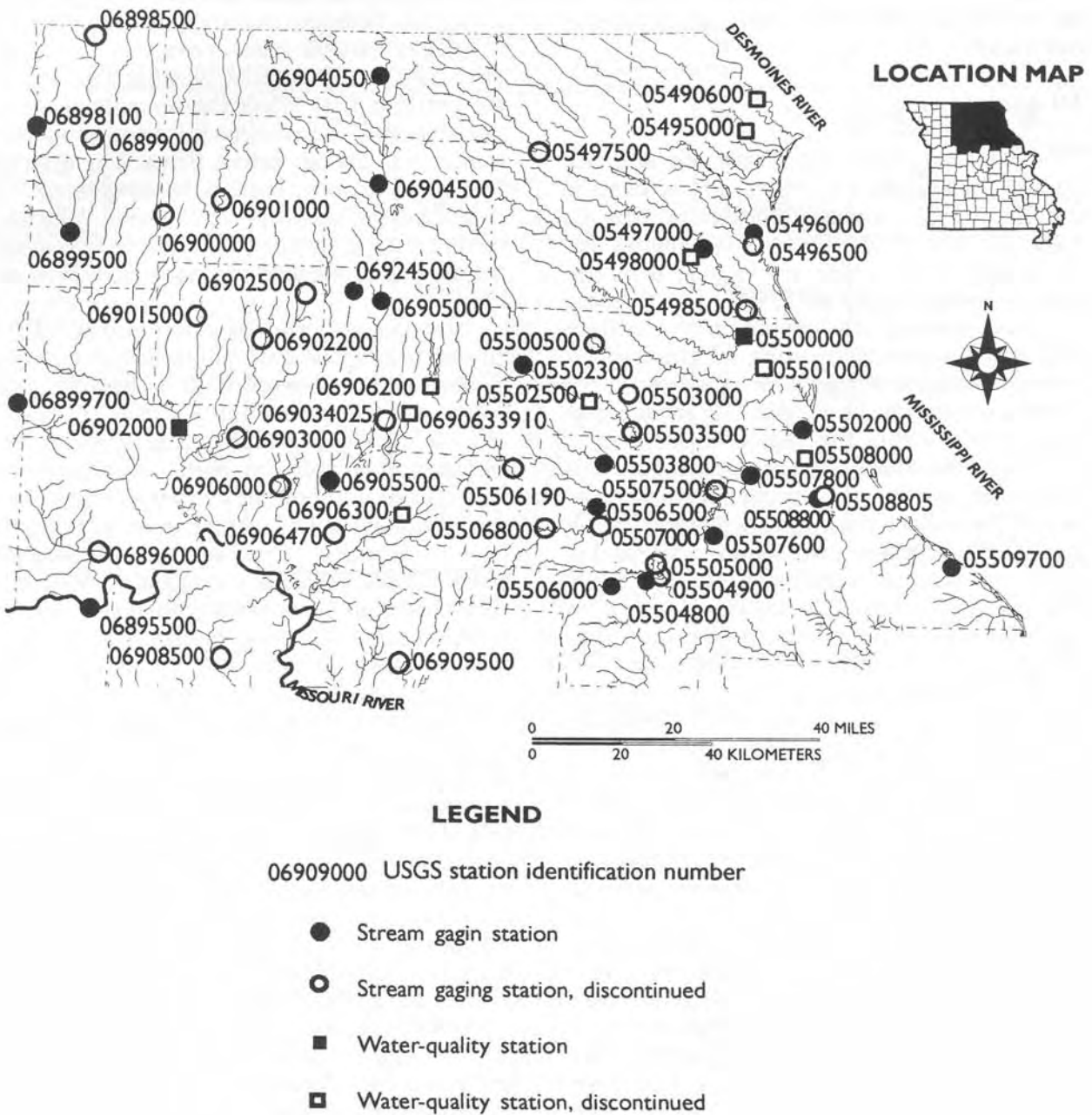


Figure 23. Locations of stream gaging and water quality gaging stations in northeastern Missouri (Source: United States Geological Survey, 1997).



Figure 24. Palmer Drought Severity Index (PDSI) regions in Missouri.



Figure 25. Number of public water supply reservoirs by county in Missouri (Source: Department of Natural Resources, 1991).

Impacts of Stream Channelization

Problem:

Stream channelization has an adverse impact on instream habitat, some water uses and riparian/floodplain activities. Channelization results in deeper and wider stream channels, which can impact infrastructure. Sedimentation from this process may also impact water use.

Discussion:

Channelization is a structural modification to streams that increases the channel's capacity to move water by straightening channels, deepening them, or both. Almost all streams in Missouri have been altered to some extent; realigned and reshaped stream channels are widespread in northern Missouri. Channelization has been common on the streams of northern Missouri. For example, the Missouri River has been channelized its entire length through Missouri, and nearly all of the Chariton River has been channelized as well (DNR/DGLS, 1986).

Stream channels have been straightened, widened, and relocated for hundreds of years. People continue to alter stream channels to make streams and their floodplains more suitable for human uses such as developing additional farmland acreage, protecting existing bottomlands, facilitating navigation, and improving drainage. However, channelization has negative impacts on streams and sometimes on the land adjacent to them.

A natural stream channel contains deep and shallow sections, known as pools and riffles, which provide habitats for a diversity of stream organisms. In a channelized stream, however, pools become filled and riffles become embedded. River plants, fish and macroinvertebrates are often physically removed by dredging operations or are negatively affected by increased turbidity. Channelization diminishes the preferred habitat of big fishes--sluggish pools and overflow areas along large rivers. Habitat diversity is lost because of the flat, uniform stream bottom, affecting aquatic organisms and some waterfowl species as well.

Channelization contributes to streambank erosion and may lead to serious downstream

flooding. A channelized stream is shorter than a natural stream, thus streamflow velocity increases due to increased channel gradient. This in turn causes higher peak discharges and shorter times to reach peak discharge, which increases the magnitude and frequency of downstream flooding. Among other things, floodwaters may damage valuable farmland and buildings constructed on the floodplain. In addition, infrastructure may be affected as bridges, pipelines and communication lines in channelized reaches are undermined, and increased sedimentation can decrease the storage capacity of any downstream reservoirs.

Flood damages are compounded along unchannelized streams downstream from extensively channelized river systems. Floodwater washes away silt, sand, and gravel and carries the sediments downstream where they may be deposited in unchannelized streams. Sedimentation of non-straightened rivers below channelized rivers, such as Locust Creek in the vicinity of Pershing State Park, is building up. This is especially destructive to fish habitat and production.

Sedimentation in Streams

Problem:

Sedimentation stemming from soil erosion deposits vast amounts of silt, sand and even gravel into ponds and streams each year. Sediment deposition results in reduced water storage space and a decrease in water quality.

Discussion:

Sedimentation from soil erosion is made of detached soil particles washed away from the land surface and deposited in rivers, lakes and streams. Considerable sedimentation occurs in many streams of northeastern Missouri, such as the Fabius and Wyaconda rivers.

Sedimentation increases turbidity (which affects aquatic biota and the cost of water treatment), fills pools and embeds riffles, making them less desirable or unsuitable for aquatic life. High sedimentation rates have contributed to the filling of reservoirs and pools in many small streams of the region. Sediment deposits lessen the effectiveness of reservoirs by reducing the volume of water they can hold. This, in turn, reduces the

amount of water available for water supply and recreation. In addition, excessive sedimentation can result in localized flooding due to reductions in channel capacity.

In addition to changes in the flow characteristics and natural patterns of rivers, sedimentation impairs water quality and damages aquatic ecosystems. Sediment and sediment-attached pollutants are the most widespread source of pollution in surface water systems, and constitute a significant pollution problem in northeastern Missouri (Todd, et. al, 1994).

Sedimentation reduces the number and kinds of aquatic invertebrates found in streams. Sensitive organisms like mayflies, stoneflies and caddisflies disappear and are replaced by more tolerant invertebrates. Sediment deposition in northeastern Missouri streams has destroyed or greatly reduced freshwater mussel and insect populations, which are an important source of food for fish. Many sensitive invertebrates inhabit the surfaces of stones and the interstitial spaces between and beneath large substrate particles, such as pebbles and cobbles. When fine sediment fills these spaces, these species are typically replaced by more tolerant ones.

Ultimately, increased turbidity and siltation can result in the reduction or loss of fish populations. Most often, fish are not killed directly by sedimentation. Rather, deaths are caused by sublethal effects such as reduced feeding and growth, respiratory impairment, reduced tolerance to disease, physiological stress and reduced reproductive success. As noted above, sediment fills the interstitial spaces of riffle substrates, which are essential to fish fry, as well as reducing water depths in pools.

Aquatic Ecosystem Health Concerns

Problem:

Aquatic habitats in and along streams are being degraded as a result of land use activities and chemicals that are toxic to stream life.

Discussion:

About 60 years ago, prior to channelization, anglers often caught flathead

and channel catfish from the Chariton and Salt rivers. About 95 percent of the fishing in this region now occurs in man-made impoundments and mostly for largemouth bass and channel catfish. The Missouri Department of Conservation (MDC) area fisheries supervisor credits the higher availability of open water fishing as increasing the actual recreational fishing opportunity. However, environmental changes affecting the aquatic habitat have caused a decrease in fishing in rivers, and have affected the diversity of aquatic plant and animal life in northeastern Missouri streams. Under certain conditions, pesticides and herbicides can reduce species population numbers, alter natural habitat, influence normal behavior, stimulate or suppress growth, affect reproductive capacity, alter nutritional content of foods, alter nutrient absorption of animals eating the food, and increase susceptibility to disease (Pimentel, 1972).

Misapplication of chemicals and toxic releases, compounded by stream channelization and row crop agriculture, where vegetative stream buffers are absent, are aquatic ecosystem health concerns in northeast Missouri. These factors have an adverse impact upon the diversity and numbers of fish and other aquatic species. Accidental releases of domestic effluent, spills, and over-applied chemicals have caused recent fish kills. The Missouri Department of Conservation and Department of Natural Resources investigated a number of fish kills in northeast Missouri in the 1990s. Uncontrolled releases of hog manure have been cited as causes, as have oil spills and contamination from other chemicals. In addition, runoff from confined areas and feed lots can discharge animal wastes directly into streams, elevating fecal coliform counts, organic loads and nutrient concentrations. The resulting eutrophication may cause dense algal growths, which can lead to dissolved oxygen depletion. This stresses fish populations and, in serious cases, can also cause fish kills.

Missouri Department of Conservation stream fish electroshock sampling data indicates that only about 20 percent of the catfish captured and released were greater than 14 inches long. Freshwater mussels have been declining in northeastern Missouri and the winged mapleleaf mussel no longer occurs in the Fox River in northeastern Missouri

(Buchanan, 1991). A chemical compound in water can exist in one or more of four states: it can exist in solution, it can be associated with biotic or abiotic surfaces, it can be suspended within the water column, or it can be incorporated (and possibly accumulated) into living and dead organisms (National Research Council, 1981).

Acute toxicity data show that insecticides can be several orders of magnitude more toxic to aquatic life than herbicides. Past research has shown that pesticides transported in water adhere to suspended organic debris, which in turn is fed upon by small invertebrates, initiating contamination of the food chain (Peterle, 1991). This can ultimately reduce the number of individuals within a species and the diversity of species present, resulting in both a reduction of the carrying capacity of a stream and impacting on the "richness of genes" of affected species by limiting the species gene pool (Draggan, et. al., 1987). Low level, chronic effects are more difficult to observe and assess in a natural system, but may be more apt to lead to long term, large scale species mortality (Peterle, 1991). Contaminants sometimes skip forage species by massing in a prey species with no observable or appreciable effect, while having major impact on the predator species (Draggan, et. al., 1987). Pesticides (such as heptachlor) may persist in the environment for decades. Chemicals that have been metabolized or degraded into another form may be as toxic or more toxic than the original chemical, thereby compounding the longevity factor (Duffus, 1980).

Loss of Riparian Corridors/ Streambank Vegetation

Problem:

Many stream reaches in northeastern Missouri have lost much of the vegetation along their banks. Loss of riparian corridors results in accelerated bank erosion, channel widening and shallowing of water, diminished water quality, and loss of aquatic and riparian habitat.

Discussion:

Clearing of streamside vegetation is a problem in northeastern Missouri. Currently, many streams have few, if any, trees on their banks. Lateral erosion due to channelization and changing land use (with associated higher runoff rates) often removes the few remaining trees on affected stream reaches. Human activity in riparian zones often results in additional tree and understory removal. Much of the lower streamside vegetation removed in northeastern Missouri stems from allowing cattle unrestricted access to riparian corridors. While not removing large trees, this does remove much of the understory vegetation that filters pollutants and traps sediment.

Riparian vegetation influences the temperature of streams and the amount of energy available to aquatic ecosystems. As trees and upper understory are lost, streams become unshaded, causing water temperatures to rise. Higher water temperatures decrease the solubility of oxygen, depressing dissolved oxygen concentrations in streams that sustain stream biota. In Missouri, riparian forests supply a significant proportion of the energy supporting food webs in streams in the form of leaves. Root systems and large woody debris from riparian trees affect physical habitat by controlling bed and bank stability, erosion, sediment transport and grade control. Root systems also retain leaves and other organic debris, provide stable substrates for invertebrates, and act as an important habitat component for fish and aquatic invertebrates.

Healthy lower understory vegetation can also improve water quality by removing the pollutants in runoff, as well as increase the biodiversity and productivity of stream communities by improving habitat and adding to the organic food base. Streamside vegetation can intercept pollutants from both ground and surface water before they reach a stream. Because cattle with unrestricted access to streambanks often remove significant amounts of streamside vegetation, the riparian zone may no longer be able to act as a filter to nutrients, sediment and other pollutants. As a result, water quality may suffer. Trampling of streambanks by cattle can result in bank slumping, and a wider and shallower channel. This results in additional streambank erosion and sedimentation.

Loss of Aquatic Species

Problem:

Stream habitat degradation in northeastern Missouri has resulted in declining mussel populations, and has caused the ranges of sensitive fish species to be significantly reduced.

Discussion:

Northeastern Missouri has a few disjunct populations of prairie and lowland fish species, such as the central mudminnow, slough darter, bluntnose darter, hornyhead chub, mottled sculpin, and Topeka shiner. These species have extremely small ranges; some are limited to a single location. As a consequence, they are vulnerable to stream habitat degradation, which results in the reduction or complete loss of species from entire basins. For example, in 1985, 85 specimens of the endangered Topeka shiner were collected from Cedar Creek in Clark County. In March 1997, not a single specimen was collected. The Topeka shiner could also be found in the Chariton River basin; in 1990, one specimen was found, and none were collected between 1992 and 1995.

Freshwater mussels are similarly vulnerable. Freshwater mussels are the most endangered fauna in North America, with over 45 percent of the 300 existing species in jeopardy. This holds true for mussels in Missouri, particularly in areas of the state such as northeastern Missouri where a combination of physical habitat alteration and declining water quality have substantially changed the free-flowing stream habitat required by freshwater mussels. Because of their unique reproductive strategy⁸, freshwater mussels are particularly susceptible to changes in water quality. Not only are the larvae extremely sensitive to water quality changes, they are susceptible to any habitat changes that impacts a species of fish the mussels rely upon for reproduction.

Increased siltation, pesticides and herbicides, and nutrients from both urban and

agricultural sources have impaired water quality in northeastern Missouri, contributing to stream habitat degradation. In addition, navigation improvements have contributed to declining freshwater mussel populations in the Upper Mississippi River; the Higgins Eye and Fat Pocketbook mussels have nearly been eliminated in Missouri's reaches of the river.

Environmental Water Interests Vs. Landowner Water Rights

Problem:

The extent of permissible reasonable use of water by a riparian landowner and its relationship to natural environmental water needs has never been fully defined in Missouri.

Discussion:

According to Missouri water law, landowners have the right to make reasonable use of the water flowing on, across, and under their properties, so long as their use of that water does not unreasonably interfere with the same rights of other riparians or their use does not markedly diminish the quality or quantity of the water. While land is individually owned, water is shared in common by all Missouri citizens.

The Missouri Clean Water Law, RSMo 644.011, states "Whereas the pollution of the water of this state constitutes a menace to public health and welfare, creates a public nuisance,... and impairs domestic, agricultural, industrial, recreational and other legitimate uses of water,... it is hereby declared to be the public policy of this state to conserve the waters of the state, and to protect, maintain, and improve the quality thereof,... and to provide for the prevention, abatement and control of new or existing water pollution..."

This law targets landowners who use groundwater and surface water as they must meet certain water quality criteria if their activities adversely affect the quality of the

⁸ In freshwater mussel reproduction, the larval stage (glochidia) is released into the water column, where it must contact, encyst upon, and metamorphose on native fish.

water exiting their property. It might also be argued that water quantity issues should be addressed with this legislation as a result of the statement "...it is hereby declared to be the public policy of this state to conserve the waters of the state, and..." However, because Missouri follows riparian water law, water quantity disputes in the past have been settled in civil court.

Problems arise when landowners, in their rightful use and enjoyment of their land, adversely affect the natural, environmental uses of adjoining or downstream water interests. Additional problems arise when trying to characterize the affected waters. Flow rates, including seasonal fluctuations, and chemical and bacteriological profiles of the waters are not always available for comparison.

Interstate Water Issues--Iowa and Missouri

Problem:

Streams flow from Iowa into Missouri across the state boundary, but no agreement exists between Missouri and Iowa to ensure that Missouri receives a fair share of the water.

Discussion:

With the exception of the Des Moines River, which forms a small part of Missouri's northeastern border, all of the streams that cross the state boundary into northeastern Missouri originate in Iowa. There are 21 streams that cross the border between Mercer and Clark counties. The largest of these is the Chariton River, which is partly controlled in Iowa by the Rathbun Dam.

The allocation of the flow of interstate streams is usually done through an interstate compact, an agreement negotiated between the states and ratified by Congress. However, the process is lengthy and usually expensive, so it is rarely pursued unless problems become severe. Currently, no agreement between Iowa and Missouri allocates

the flow of interstate streams equitably between the two states. Thus far, there have been no serious disagreements related to water use, because water use in Iowa has not depleted the interstate streams enough to cause concern in Missouri. However, the lack of an agreement between the two states could present real problems for water users in northeastern Missouri, especially during drought, given the extent to which the region relies upon surface water for water supply.

Lack of Emergency Service Access Points on Lakes and Rivers

Problem:

A shortage of emergency service access points on lakes and rivers in northeastern Missouri hampers emergency response efforts in times of crisis.

Discussion:

The Missouri Constitution charges the Missouri Department of Public Safety (DPS) to protect and safeguard the lives and property of the people of the state. The Missouri State Water Patrol, which is administered by the Department of Public Safety, is the state's primary waterborne emergency response agency. The mission of the Water Patrol is to "preserve the peace, educate the public in boating and water safety, investigate criminal activities and enforce the laws on the waters of the state and adjoining lands for our citizens and visitors so they can safely enjoy the abundant resources of the state."⁹ The Missouri Department of Conservation, Highway Patrol, County Sheriff Offices, Department of Natural Resources, Army Corps of Engineers and Coast Guard provide additional assistance (Huenink, personal communication, 1997). This charge includes responding to situations requiring emergency assistance. By its nature, emergency response must be rapid. Limited and nonex-

⁹ From the Missouri State Water Patrol Strategic Plan mission statement.

istent access to the lake or river delays emergency assistance in getting to the site. Typical emergency response situations include locating missing persons, medical emergencies, bad weather rescues, recovery of victims, and physical disasters such as pipeline breaks (Huenink, personal communication, 1997). Emergencies comprise both immediate, short term crises, such as capsizing or swamping boats with victims in the water, and longer term efforts, such as search and recovery work.

While accessible facilities are commonly available on the larger public lakes such as Long Branch, Thousand Hills, and Mark Twain, usable access points are fewer or non-existent on many private lakes and on rivers like the Grand, Chariton, and the lower reaches of the Salt. One area in particular is heavily used by boaters but has very limited access. This area is on the Mississippi River between Clarksville and Winfield (Huenink, personal communication, 1997). The Missouri Department of Conservation identifies only three public boat ramps servicing this reach of the river--Hamburg Ferry Access near Annada, Norton Woods Access at Elsberry and Leach Memorial Conservation Area northeast of Foley (MDC, 1996b).

Boat launch access points may be limited by several factors. Most obvious is the lack of an all-weather permanent ramp. Other limiting factors include a lack of roads leading to the water's edge, lack of easements across private property to the lake or river, and the physical characteristics of northeastern Missouri river and lake banks (Huenink, personal communication, 1997). Because of its glaciated topography, many stream and river banks are steep, vertically layered deep top soils. When saturated these top soils are extremely slick and deeply

mudded. When dry, they may easily crumble, preventing vehicular access to the water's edge. Water level, which is too high or too low, may also prevent access. Many times emergency response is limited to hand portage of lightweight john boats across rough, wooded, marshy or slippery ground to the water's edge.

According to 1995 statistics there are 307,000 registered boats and 200,000 additional boats not requiring registration in Missouri. The Water Patrol estimates that 20,000 out-of-state boaters use Missouri waterways each weekend (DPS, 1997). In 1996, the Water Patrol responded to 382 boating accidents statewide. From the beginning of 1997 through the end of October the Water Patrol had responded to 410 boating accidents. Water Patrol District 5 (covering northeast Missouri) responded to 41 and 42 boating accidents, respectively, during the same time frames (Huenink, personal communication, 1997). A complete list of 1996 boating accidents occurring in District 5 (which includes location, type, and cause of accident) is provided in table 6.

DuCharme and Miller (1996) identify water-based recreation as a significant outdoor recreational activity in Missouri, which acts as a catalyst for tourism. Some of the fastest growing areas of the state are near public recreational lakes (DuCharme and Miller, 1996). The *1991-1996 Missouri Statewide Comprehensive Outdoor Recreation Plan* (SCORP) projected a total of 147 million activity days statewide for water based recreation, which included swimming, fishing, motor boating, water skiing, canoeing, non-motor/row boating, and sailing. It also estimated there are 36,558 acres of lakes and 7,014 miles of streams in northern Missouri (DuCharme and Miller, 1996).

Name of Body of Water	Type of Accident	Cause of Accident	Fatalities	Injuries	Damage > \$500	Alcohol Involved
Callaway Lake	Capsizing	Hazardous Waters	1	0	No	No
Farm Pond	Falls Overboard		1	0	No	No
Locust Creek	Capsizing	Hazardous Waters	1	0	No	No
Mark Twain Lake	Collision with Floating Object	Hazardous Waters	1	1	Yes	Yes
Mark Twain Lake	Falls Overboard	Standing/Sitting on gunwales, bow, tran	0	1	No	No
Mark Twain Lake	Capsizing	Hazardous Waters	0	3	Yes	No
Mark Twain Lake	Collision with Fixed Object	Hazardous Waters	0	0	Yes	No
Mark Twain Lake	Flooding/Swamping	Weather	0	0	Yes	No
Mark Twain Lake	Struck by Motor/Propeller	Improper Loading	0	1	No	No
Mark Twain Lake	Flooding/Swamping	Hull Failure	0	0	Yes	No
Mark Twain Lake	Collision with Vessel	Operator Inattention	0	0	No	No
Mark Twain Lake	Capsizing	Operator Inexperience	0	0	Yes	No
Mark Twain Lake	Collision with Vessel	Operator Inexperience	0	0	Yes	No
Mark Twain Lake	Skier Mishap	Passenger/Skier Behavior	0	1	No	No
Mark Twain Lake	Flooding/Swamping	Weather	1	0	Yes	No
Mississippi River	Collision with Floating Object	Hazardous Waters	0	0	Yes	Yes
Mississippi River	Fire/Explosion (Other than Fuel)	Weather	0	0	Yes	No
Mississippi River	Fire/Explosion (Other than Fuel)	Machinery Failure	0	0	Yes	No
Mississippi River	Collision with Vessel	Careless/Reckless Operation	0	0	Yes	No
Mississippi River	Skier Mishap	Passenger/Skier Behavior	0	1	No	No
Mississippi River	Collision with Fixed Object	No Proper Lookout	0	0	Yes	No
Mississippi River	Flooding/Swamping		0	0	Yes	No
Mississippi River	Flooding/Swamping	Weather	0	0	Yes	No
Mississippi River	Collision with Vessel	Weather	0	2	Yes	Yes
Mississippi River	Collision with Vessel	Weather	0	2	No	No
Mississippi River	Collision with Vessel	Careless/Reckless Operation	0	1	Yes	Yes
Mississippi River	Collision with Fixed Object	Hazardous Waters	0	4	Yes	No
Mississippi River	Fire/Explosion (Fuel)	Machinery Failure	0	0	Yes	No
Mississippi River	Falls Overboard	Careless/Reckless Operation	0	1	No	Yes
Mississippi River	Grounding	Hazardous Waters	0	1	No	Yes
Mississippi River	Collision with Vessel	Careless/Reckless Operation	0	0	Yes	Yes
Mississippi River	Collision with Vessel	Careless/Reckless Operation	0	0	Yes	No
Mississippi River	Collision with Vessel	Machinery/Failure	0	0	No	No
Mississippi River	Collision with Floating Object	Hazardous Waters	0	0	Yes	No
Mississippi River	Fire Explosion (Fuel)		0	0	Yes	No
Mississippi River	Grounding	Hazardous Waters	0	0	Yes	No
Mississippi River	Flooding/Swamping	Overloading	3	2	Yes	Yes
Mississippi River	Fire/Explosion (Other than Fuel)		0	0	Yes	No
Thomas Hill Lake	Capsizing	Hazardous Waters	0	0	Yes	No
Thomas Hill Lake	Collision with Vessel	No Proper Lookout	0	2	No	No
Thomas Hill Lake	Flooding/Swamping	Weather	0	0	No	No
TOTAL District Boating Accidents = 41 TOTAL Fatalities = 8 TOTAL Injuries = 23 Note: Blank areas in "Cause of Accident" indicates the cause was unknown						

Table 6. 1996 boating accidents: Missouri State Water Patrol District 5 (data source: Missouri Department of Public Safety, Missouri State Water Patrol, 1996).



Regional Observations

This report documents water use problems that have been identified in northeastern Missouri. In addition to water use problems, however, several “success stories” and opportunities in water use have been recognized as well. Although the goal of this series is to identify problems rather than offer solutions, some of these findings are described below. By taking note of successes (and opportunities for success), we recognize approaches that work, and can use them as stepping stones to problem resolution.

In northeastern Missouri, public (and private) partnerships and cooperation emerged as positive forces in addressing regional water “needs”. Some examples are briefly described in the following paragraphs:

Management-intensive Grazing

Management-intensive Grazing (MiG) and rotational grazing may provide an increased opportunity for clean streams and lakes. MiG calls for a rotational grazing program instead of the more traditional continuous grazing. In continuous grazing situations, cattle (and other livestock) are left on the same field for long periods of time, often until the field is over grazed, to the detriment of the native grasses and topsoil. Rotational grazing, in practice, requires animals to be rotated to another pasture before they can cause damage to plants or soil. Rotational grazing uses more extensive divisional fencing and water systems, which partition the fields. For environmental and economic reasons, it is advantageous to rotate animals through pastures

frequently. Frequent rotations allow unused pastures to “rest,” restoring trampled high-use areas adjacent to streams and lakes and allows grasses to regrow. Management-intensive grazing requires that water sources be brought to the animals, rather than requiring the animals to walk long distances to water sources. Developing, creating and restoring local water sources (such as springs and ponds), and extending water lines reduces the need to provide access to streams. Agricultural benefits include improved livestock gains, higher stocking rates per acre, and more efficiently used pastures. Environmental benefits include reduced fertilizer usage through a more even manure distribution, reduced riparian damage, less topsoil erosion, and more stable streambanks, and diminished risk from contaminants in runoff.

Management-intensive grazing techniques have been known for many years, but only recently have state and federal governments recognized the value of these techniques to natural resource conservation. Currently the United States Department of Agriculture through its environmental quality incentives program, the Missouri Department of Natural Resources through its rotational grazing incentives, and the Missouri Department of Conservation through its stream bank and watering systems cost-share programs have all invested public funds to benefit the usage of Missouri’s natural resources for animal production. The University of Missouri Agricultural Experiment Station and Extension Service has developed expertise in MiG principles at their field stations. They also conduct staff seminars throughout Missouri.

Clarence Cannon Dam--Mark Twain Lake

Mark Twain Lake was constructed as a result of federal, state and local partnerships. The people and agencies involved represented many interests, but were able to work towards a common goal and create a multipurpose reservoir. The Clarence Cannon Wholesale Water Commission (CCWWC), which withdraws water from the reservoir, is an example of long-term coordinated water planning. It provides treated water on a wholesale basis to member municipalities and rural water districts. Through the efforts of the Clarence Cannon Wholesale Water Commission a reliable supply of water is readily available to a large area of northeastern Missouri.

Clarence Cannon Dam, a major U.S. Army, Corps of Engineers, project on the Salt River, was completed in 1984. As part of the project, the State of Missouri asked for 20,000 acre-feet of water supply storage in Mark Twain Lake, enough storage in most years to provide 16 million gallons of water per day to meet projected water needs far into the future. This storage, provided by the federal government under provisions of the Water-Supply Act of 1958, must be paid for by a nonfederal sponsor, in this case the state of Missouri.

To address the repayment of costs, and at the same time market the water, the state contracted with the U.S. Army, Corps of Engineers, to share the water with CCWWC. Currently, CCWWC contracts for 3.1 million gallons per day, leaving the remaining 12.9 million gallons per day in state ownership. The CCWWC has aggressively pursued marketing its share of the water, currently serving 18 municipal and rural water suppliers. Under terms of the current contract, the water supply storage costs (and water costs to ratepayers) will drop substantially once the principal has been repaid. The availability of water from Mark Twain Lake through the Clarence Cannon Wholesale Water Commission provides an attractive marketing advantage--abundant clean drinking water at a stable price and in quantities far greater than current consumption.

Partnership-building efforts did not end after the completion of Mark Twain Lake. The

Natural Resources Conservation Service (NRCS) is currently directing the Mark Twain Water Quality Initiative, a cooperative effort between NRCS, DNR, the University of Missouri, the Missouri Department of Conservation and landowners to demonstrate and evaluate the effectiveness of "total resource management plans" to address water quality problems in the Mark Twain Lake watershed. Using an interdisciplinary approach, the project seeks to reduce the quantities of sediment and chemical pollutants (nutrients and pesticides entering the system and being deposited in public drinking water reservoirs in the region and Mark Twain Lake at the mouth of the project area (DNR/DEQ, 1997a). In addition, 16 field personnel were trained in the formulation and implementation of nutrient/pesticide management strategies; these specialists are expected to expand the use of total resource management planning in other regions of Missouri (DNR/DEQ, 1997c).

Water Quality Improvements in Public Water Supplies

Although water supply problems persist in northeastern Missouri, regional water supply efforts have led to improvements in drinking water quality. According to the Missouri Department of Health, the statewide expansion of public water districts has substantially reduced the number of Missourians drinking contaminated water. For example, the number of people in the Department of Health (DOH) Northeast District drinking nitrate-contaminated water has fallen 50 percent in recent years. In 1990, 24 percent of the samples from the Northeast District analyzed by the State Public Health Laboratory exceeded the drinking water standard for nitrates; by 1995, exceedences had dropped to 12 percent (Maley, written communication, 1997).

Water quality in northeastern Missouri has also improved through an increased awareness of water resources issues by agricultural producers, due to the availability of quality assurance plans offered by various agricultural associations and commercial enterprises (Young, written communication, 1997).

Conservation Reserve Program

In 1997, the United States Department of Agriculture (USDA) began to implement an environmental benefits ranking system, establishing new eligibility criteria for inclusion in the Conservation Reserve Program (CRP). Now, the program may accept the enrollment of streamside riparian corridors and filter strips for up to 15 years, a practice not allowed under the previous CRP rules. The Conservation Reserve Program is the largest land conservation program in the nation. It was established by Congress in the 1985 Farm Act as a voluntary, long-term cropland banking program. The USDA provides participants with annual payments and cost-share assistance in exchange for retiring highly erodible or environmentally sensitive cropland for a period of 10 to 15 years. Since its inception, landowners in Missouri have retired more than 1.7 million acres of land under the CRP. Most of the CRP contract acreage in Missouri is distributed north of the Missouri River, much of it in northeastern Missouri (figure 26).

These changes have been positive for the environment in Missouri (Lee, personal communication, 1998). Currently, the Conservation Reserve Program protects approximately 700 million tons of topsoil from wind and water erosion nationwide each year. In northeastern Missouri, about 15,000 tons of soil are saved every year, approximately 50 percent of the

amount saved statewide. In addition, the program restores and maintains wildlife habitat; the areal extent of habitat created nationally through the CRP is equivalent in size to the state of Iowa. The USDA believes so strongly in its new environmental benefits promotions that they are reserving CRP funds for future possible signups of riparian corridors.

Reductions in Soil Erosion

Partnership building has contributed to reduced soil erosion in northeastern Missouri and throughout the rest of the state. Through the combined efforts of state and federal agencies, local officials and private landowners, soil erosion statewide was reduced by nearly 76 million tons between 1982 and 1992 (DNR/DGLS, 1996). Between 1982 and 1992, 27 million tons of soil were saved in northeast Missouri. Local landowners, county soil and water conservation districts, the USDA Natural Resources Conservation Service, the Missouri Departments of Natural Resources, Conservation and Agriculture, the University of Missouri Extension and others all play important roles in reducing soil erosion through various programs. For example, the Special Area Land Treatment (SALT) program, administered by the Department of Natural Resources, brings landowners in watersheds together to help solve soil erosion and water quality problems (DNR/DGLS, 1997).

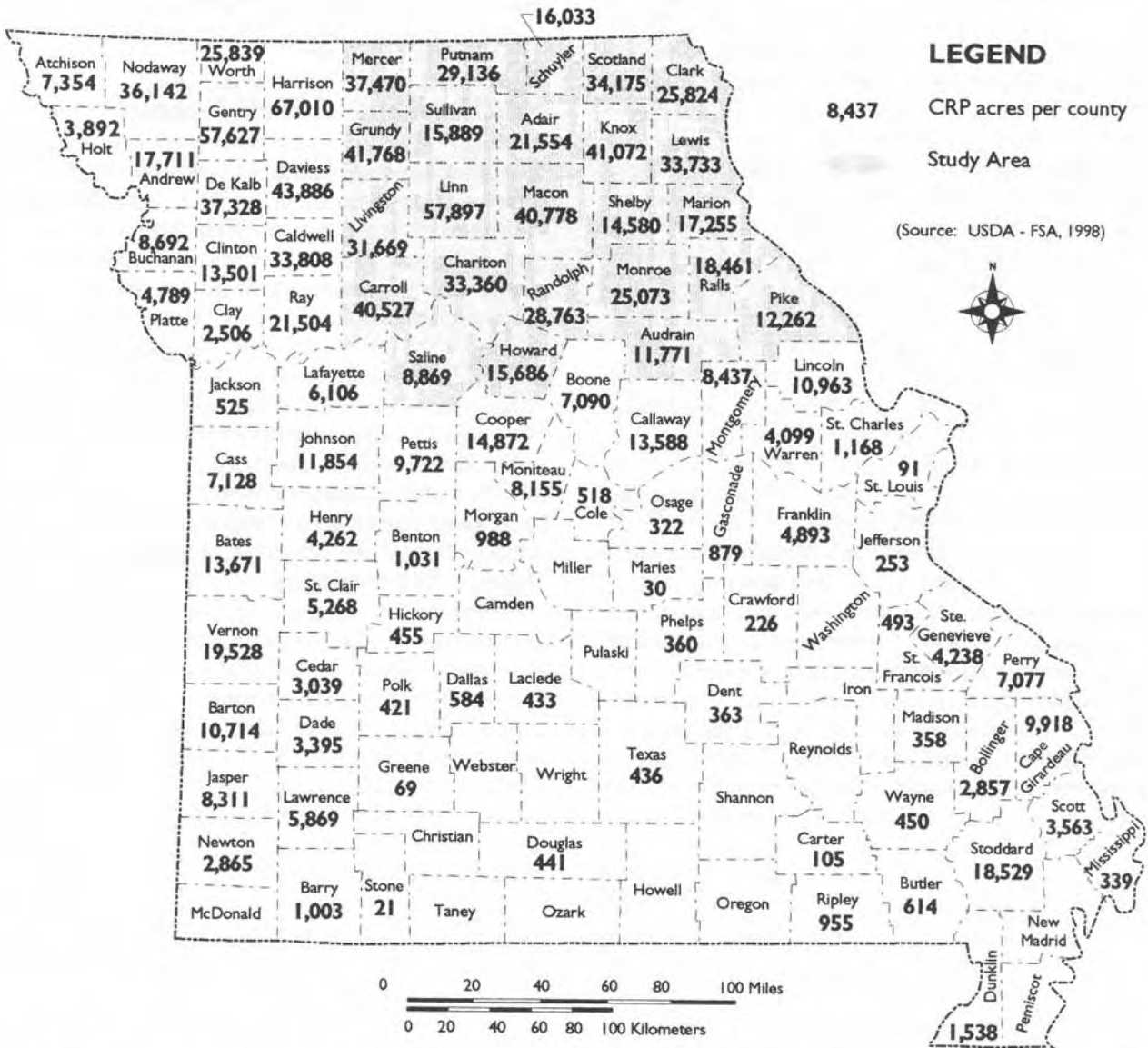


Figure 26. Conservation Reserve Program (CRP) acreage in Missouri (Source: United States Department of Agriculture- Farm Services Agency, 1998).



Regional Water Use Opportunities

Several water use “opportunities” were also suggested by some contributors to this report. These border on recommendations, and for this reason, were not fully developed in this phase. Water use opportunities are presented in this section to stimulate further thought and discussion, without endorsement of feasibility or merit.

Mark Twain Lake

The development of Mark Twain Lake, as mentioned above, is an example of successful partnership building. As a regional water resource, it has considerable untapped potential as well. Water supply is one of the designated purposes of Mark Twain Lake. Currently, only a fraction of the 16 million gallons of water available daily is used for water supply. Although domestic water use is the most common water supply application in northeastern Missouri (figure 11), commercial and industrial water supply allocations are substantial as well. The unused portion of Mark Twain Lake’s water supply allocation may provide additional benefits in terms of increased domestic water availability, and increased water availability for industrial applications, with associated economic gains.

During drought, opportunities may exist to supplement agricultural water requirements using water from Mark Twain Lake and other lakes within the region. In dry conditions, the water supply of farm ponds and small reservoirs is quickly exhausted, causing hardships for livestock producers. It may be possible to resupply dry ponds and reservoirs from these lakes, and provide water for pumping stations.

Opportunities may also exist to enhance the recreational use of Mark Twain Lake through improved access and marketing.

Major Rivers

The Missouri and Mississippi rivers may also be resources that are not fully developed for many uses. Both rivers serve as transportation corridors that provide a means to move large volumes of commodities at reasonable costs to shippers. Opportunities may exist to enhance navigation through the development of intermodal terminals, developing more efficient loading/unloading capabilities, improving navigation infrastructure, and providing ready access to ports by both rail and truck transport.

Current projections anticipate the near doubling of grain production in the four states of the upper Mississippi River by the year 2030, necessitating greatly increased navigation capacity. Presently, the Corps of Engineers is working on a comprehensive navigation study designed to address how to increase overall shipping capacity by installing 1,200-foot locks at some dams. These would replace the current 600-foot locks, allowing more barges to be locked through at the same time.

The issue of the century is the allocation of Missouri River water. Iowa and Missouri are riparian water law states. Other states of the Missouri River Basin are appropriation water law states, and allocate water. The overriding issues of the 1930s and 1940s were a devastating multi-year drought, and the great need for flood control in the Lower Missouri and Lower Mississippi River floodplains. The federal government’s response to these large issues was the Pick-Sloan Plan for major reservoirs in the Upper Missouri River Valley.

Placement of six main stem Missouri River reservoirs in the upper basin was accomplished to attenuate downstream flood-

ing and hold water back for augmenting low flows in time of drought and for irrigation; hydroelectric power and flows for navigation were other purposes of the legislation. Other purposes have been added by amending legislation, over the years, such as fish and wildlife, recreation, and water quality. Major cities in Missouri are tied to the Missouri River for water supply, either from the river itself, or from the flood plain aquifer. In addition, some of the best wetland habitat and agricultural lands in Missouri are located in the Missouri River floodplain.

Today, demands by upper basin states and Indian tribes for more water from the river and its reservoirs could actually deplete the lower river during an extreme drought. There is a call by some environmental groups to raise river levels in springtime for fish spawning habitat, that would raise water levels in agricultural fields.

Recently, the U.S. government and states have begun various land acquisitions and levee alterations to improve fish and wildlife habitat. Indian water rights, recognized by old treaties, must be resolved. The State of Missouri must recognize the opportunities for fisheries improvements, threatened species' habitat improvements, enjoyment of water-based recreation, and, most importantly, the extremely valuable grain production capacity of prime agricultural lands near the Missouri River.

Wetland Mitigation Banking

Missouri's wetlands perform many functions, such as providing fish and wildlife habitat, reducing flood damages, and improving water quality. Missouri's Wetland Conservation Plan recommends an increase in the quantity and quality of the state's wetland resource base, and wetland mitigation banking may provide a means to achieve that goal.

The *Federal Guidance for the Establishment, Use and Operation of Mitigation Banks* (Federal Register, November 28, 1995) defines wetland mitigation banking as "wetland restoration, creation, enhancement, and (in exceptional circumstances) preservation undertaken expressly for the purpose of compensating for unavoidable wetland losses in advance of development actions, when such compensa-

tion cannot be achieved at the development site or would not be as environmentally beneficial." In essence, wetland mitigation banking allows developers to purchase credit from a wetland bank that uses the funds to create, restore, enhance or preserve other wetlands. After all credits have been withdrawn from the bank and spent, it is closed. The wetlands that have been created, restored, or enhanced are then donated to a responsible public entity and protected from destruction. When authorized developments are undertaken, developers may then trade the credits as compensation for unavoidable wetland losses during construction.

The advantages and disadvantages of wetland mitigation banking are numerous and widely debated. Regulatory agencies and developers view wetland mitigation banking as a comprehensive, ecologically sound approach toward achieving "no net loss" of wetlands. Some environmental groups, on the other hand, have criticized this approach, citing a lack of an acceptable functional assessment methodology and asking why developers should be compensated for destroyed wetlands by preserving wetlands already protected by the law. Currently, Missouri does not have mitigation banking legislation, nor does it have any wetland acreage in mitigation banks. However, many state and federal agencies have expressed interest in and have been evaluating the possibility of wetland mitigation banking in Missouri.

Value-Added Processing of Agricultural and Industrial Products

Opportunities may also exist to make use of northeastern Missouri's water resources in value-added processing of agricultural and industrial products. Value-added processing is a manufacturing activity, which improves a raw or less processed article or product into a more finished item or food product. Northeastern Missouri has a number of food processing plants. However, most agricultural products of this region are shipped to market raw, in bulk, by truck, train or barge. Value-added processing often reduces the bulk of a product, making shipping and storage easier. However, value-added production opportuni-

ties require more water in processing. In addition, food processing and specialty industries employ local residents, strengthening the regional economy. The added value then accrues to the region upon the marketing of the product.

Low Flow Augmentation

Low flows in northeastern Missouri's streams are a factor in many of the water use problems identified in this report. Base streamflows in northeastern Missouri, already naturally low, may be further reduced by human activity. It has been suggested that impoundments of various sizes, from farm ponds to water supply reservoirs, could be equipped

with outlet structures designed to release water slowly. Low flows in streams with impoundments could be increased in this way, restoring them to more desirable levels and potentially improving aquatic habitat.

The complexities of this issue are substantial, however. While low flows can present difficulties in managing fisheries in rivers and streams, it is unclear how much augmenting low flows will benefit aquatic life. During dry periods, essential human water requirements receive priority over fish and wildlife needs, a time when low flow augmentation would be most critical to aquatic life. However, the potential benefits (such as wastewater assimilation and habitat improvement) make low flow augmentation worthy of further study.



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Comment Received

The Northeastern Missouri report was reviewed at several stages of preparation. Ultimately, the report was added to the Department of Natural Resources' Internet home page for access by the public. Presented in two forms, (1) a summary of the problems and a summary of the successes (opportunities), and (2) the full text of the report, the Department sought public participation in the review and comment process.

The overview was downloaded from the Internet pages 122 times, and the full text was downloaded 86 times from outside the department. In-house contacts were not counted. There was one review comment received on the draft report. Here is the comment and the response.

From: Mr. Scott Totten, deputy director, DNR Division of Environmental Quality, Jefferson City, dated June 29, 1999 (edited)--

Comment: Water use in this part of the state [Northeastern Missouri] has been affected by Ag chemicals, particularly atrazine. This has put several of the [public drinking water] supplies into a noncompliance mode and several water bodies are on the Water Pollution Control Program's 1998 [Clean Water Act Section] 303(d) list. You may wish to include these in your report.

Response from the Water Resources Program:

Section 303(d) of the federal Clean Water Act requires the state to prepare a list of waters of the state not meeting water quality standards, for submission to the Environmental Protection Agency. The Northeastern Missouri water bodies listed on the DNR Section 303(d) Category 1 list (required to have Total Maximum Daily Loads [TMDLs] set by the state) are: LaBelle Lakes numbers 1 and 2, Lewis County, both for atrazine contamination; Mark Twain Lake, Ralls County, also for atrazine contamination; Monroe City Route J Lake, Ralls County, for both atrazine and cyanazine contamination; and Vandalia Lake, Pike County, for atrazine contamination. On the Category 2 list (required to have water quality monitoring performed) are: Long Branch Lake, Macon County, for cyanazine contamination; and Wyaconda Lake, Clark County, for atrazine contamination.

This chemical pollution issue was not raised as a conspicuous problem in early discussions in the Northeastern Missouri region, however, it was raised in the Central Missouri region. Nonpoint source pollution from pesticide runoff is a topic in the pending Central Missouri regional report. Atrazine, cyanazine, and other herbicides are used to prevent weed growth. Several approaches are being taken to reduce the problem of herbicide runoff to water bodies, and other approaches are being taken to assure that delivered tap water is safe for consumers.

Thank you for commenting.



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